

Animal Waste Effects Upon Crop
Production, Soil and Runoff Waters

South Dakota State Univ., Brookings

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EPA-600/2-81-230
October 1981

ANIMAL WASTE EFFECTS UPON
CROP PRODUCTION, SOIL AND RUNOFF WATERS

by

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Grant Number R803662

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FOREWORD

EPA is charged by Congress to protect the Nation's land, air and water systems. Under a mandate of national environmental laws focused on air and water quality, solid waste management and the control of toxic substances, pesticides, noise, and radiation, the Agency strives to formulate and implement actions which lead to a compatible balance between human activities and the ability of natural systems to support and nurture life. In partial response to these mandates, the Robert S. Kerr Environmental Research Laboratory, Ada, Oklahoma, is charged with the mission to manage research programs to investigate the nature, transport, fate, and management of pollutants in groundwater and to develop and demonstrate technologies for treating wastewaters with soils and other natural systems; for controlling pollution from irrigated crop and animal production agricultural activities; for controlling pollution from petroleum refining and petrochemical industries; and for managing pollution resulting from combinations of industrial/industrial and industrial/municipal wastewaters.

This project was initiated to provide insights as to the environmentally acceptable methods for the disposal of animal production wastes to croplands and soils. This evaluation was carried out in the Northern High Plains feeding region. The results obtained will, when combined with the technologies developed by similar studies conducted in other climatic regions, be utilized to promulgate national animal wastes disposal guidelines which are compatible with national goals for the enhancement and protection of our environment.

Clinton W. Hall

Clinton W. Hall

Director

Robert S. Kerr Environmental
Research Laboratory

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ABSTRACT

This investigation was initiated to study the effects of application of differing rates of manure to the land on crops, soil, and runoff water. The study was conducted under field conditions in the sub-humid climate of the Northern Great Plains. Manure application rates included levels from 0 to 180 MT/ha/yr. Manure applied to field plots was incorporated using a chisel plow as soon after application as possible. The test crop grown on the manure treatment plots was corn. One-half of the field plots were instrumented to automatically collect samples of any runoff waters leaving the plots.

Soil salinity levels increased due to high rates of application so that the entire profile was saline. Corn yields were variable and low due to drought stress and saline conditions. Runoff occurred only twice during the course of the study. Chemical analysis of runoff waters indicated almost no differences due to plot treatments. Natural precipitation occurring after the cessation of manure treatments leached the surface soil to a non-saline condition during the first year. Although crop production was generally poor on the waste treatment plots, runoff waters from the plots did not reflect the waste treatments.

This report is submitted in fulfillment of Grant No. R803662-01-0 by the Robert S. Kerr Environmental Research Laboratory of the Environmental Protection Agency. This report covers the period from March 1, 1975 through June 30, 1978, and work was completed as of March, 1979.

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CONTENTS

Foreword	iii
Abstract	iv
Figures	vi
Tables	vii
Abbreviations and Symbols	viii
Acknowledgement	ix
1. Introduction	1
2. Conclusions	3
3. Recommendations	4
4. Background	5
5. Methods and Materials	10
6. Results and Discussion	16
References	38
Appendices	
A. Plot Soil Chemical Data and Statistical Treatment	42
B. Water Infiltration and Chemical Analyses	63
C. Plant Populations and Crop Yields	71

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FIGURES

<u>Number</u>		<u>Page</u>
1	Field plot diagram for manure treatment study	13
2	Accumulated water infiltration into plots receiving low salt manure treatments (1975 data)	22
3	Accumulated water infiltration into plots receiving high salt manure treatments (1975 data)	23
4	Accumulated water infiltration into plots receiving low salt manure treatments (1976 data)	24
5	Accumulated water infiltration into plots receiving high salt manure treatments (1976 data)	25
6	Plant height at two sample dates during 1975 growing season	32
7	Plant height at three sample dates during 1976 growing season	33

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TABLES

<u>Number</u>		<u>Page</u>
1	Detailed Profile Description of the Egan Silty Clay Loam Soil	11
2	Manure Application Rates Prior to 1974 and 1975 Growing Seasons	17
3	Average Composition of Manure Applied to Field Plots Prior to the 1975 Growing Season	17
4	Monthly Precipitation for Southeast South Dakota Experiment Farm	18
5	Average Electrical Conductivity of the Saturation Extracts for the Surface 30 cm of Plot Soils	19
6	Electrical Conductivity of the Subsurface Soil Following Treatment	20
7	Average Cation Exchange Capacity, Exchangeable Sodium Percentage, and Exchangeable Potassium Percentage, 0-30 cm Profile Depth	21
8	Average Water Stability Ratio	27
9	Average Organic Matter Content of the 0-30 cm Profile Depth	28
10	Chemical Data for Runoff Waters Collected June 22, 1977 from Plots Shown	29
11	Chemical Data for Runoff Waters Collected March 20, 1978	30
12	Average Plant Populations	31
13	Corn Borer Damage Survey 7-21-76	34
14	K/Ca+Mg Values of Corn Leaf Samples	35
15	Average Silage Yields	36
16	Average Ear Corn Yields	37

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LIST OF ABBREVIATIONS AND SYMBOLS

ABBREVIATIONS

ac -- acres
BOD -- biological oxygen demand
CEC -- cation exchange capacity
CK -- check (untreated plot)
cm -- centimeters
COD -- chemical oxygen demand
DF -- degrees of freedom
DS -- dissolved solids
EC -- electrical conductivity
EPP -- exchangeable potassium
percentage
ESP -- exchangeable sodium
percentage
H -- high salt
ha -- hectare
hr -- hour
i -- infiltration (water)
in -- inch

kg -- kilogram
l -- liter
L -- low salt
m -- meter
meq -- milliequivalents
mmhos -- millimhos
MS -- mean square
MT -- metric tons
ppm -- parts per million
SAR -- sodium adsorption ratio
SS -- suspended solids or sum
of squares
TS -- total solids
VS -- volatile solids
WSR -- water stability ratio
Y, YR -- yellow and yellow red
(soil colors)
yr -- year

SYMBOLS

Ca -- calcium
Cl -- chlorine
K -- potassium
Mg -- magnesium
N -- nitrogen
Na -- sodium
NO₃-N -- nitrate nitrogen
P -- phosphorus
pH -- acidity

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SECTION 1

INTRODUCTION

A result of making agriculture more cost effective has been and continues to be a shift from the small diversified operation towards larger, more specialized agricultural enterprises. In the sector of agriculture engaged in the production of animal products for the consumer's table, this has meant a concentration of larger numbers of animals on smaller tracts of land. The concentration of animals necessarily gives rise to large accumulations of animal wastes in a small area. The disposal of these wastes is a major problem confronting producers of animal products.

A seemingly large number of alternatives are available to the producer for waste disposal. These alternatives run the gamut from land application through refeeding and methane production to incineration; however, nearly all disposal methods leave by-products which require further disposal. The prohibitive costs of many of these methods combined with legislation prohibiting the dumping of wastes into waterways ultimately results in application of most animal wastes to the soil.

The area of land available to the operator for disposal, and the distance wastes must be hauled to the disposal site are factors which in practice influence application rates. Hauling distances influence application costs and as a result make it attractive to dispose of wastes close to the production site.

The operator with little available land and large amounts of wastes to be removed from the production facility may view the land solely as a disposal site with little regard for future productivity. Prime concerns with that type of operation are adequate incorporation of the wastes to minimize runoff and odor problems and precautions to prevent leaching of toxic substances to ground water.

The operator with sufficient land to serve as a disposal site and a clear commitment to maintaining the productivity of his land may view animal wastes as a resource capable of reducing his fertilizer costs. This operator must concern himself with factors that reduce the value of crops grown on his land, factors that limit its productivity, or with pollutants that affect the soil or waters. Nitrates and potassium may accumulate in plants to levels toxic to animals. Salts present in the waste may cause the soil solution to exhibit a high osmotic potential and limit water availability to plants. Adsorption of monovalent cations on soil clays may cause degradation of soil structure and limit movement of water into and through the soil.

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An experiment was conducted at the Southeast South Dakota Experiment Farm to establish relationships between animal wastes applied to the soil and their effect on the soil and plants grown on it. Feeder steers were fed from approximately 200 to 540 kg with a typical finishing ration which varied only in the amount of sodium chloride (NaCl) added to it. The wastes produced by the steers were collected, segregated according to NaCl levels in the ration, and spread on field plots at rates up to 180 MT/ha/yr.

The objectives of this investigation were: 1) to determine if, under dryland conditions, the salts present in manure applied to the land would accumulate in the root zone to levels high enough to seriously limit crop production, 2) to determine if the ratio of monovalent to divalent cations present in the manure would upset the balance of these cations in the soil and cause soil structure problems, 3) to determine if the salts and organic matter added by the manure would affect the ability of the soil to transmit water, and 4) to determine the effect of applied wastes upon the quantity and quality of runoff waters.

In a previous study conducted by Horton, Wiersma, and Halbeisen (76), the effect of salt level and roughage content of a ration for beef steers upon animal performance and manure characteristics was investigated. The present study extended the earlier work to include effects upon the land and upon runoff waters leaving the treated land. Information from the two studies will be useful in determining the value of manure for crop production during periods of limited rainfall. The soil salinity and runoff water quality data will be useful in developing best management practices under Section 208 P.L. 92-500.

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SECTION 2 CONCLUSIONS

1. Soils developed under sub-humid conditions such as the Northern Great Plains frequently contain considerable quantities of salt within their profiles. When only the surface is naturally leached free of salts, addition of large quantities of manure can salinize the entire soil profile and affect crop production.
2. Although exchangeable sodium levels in the soils studied increased due to manure application, the levels of exchangeable sodium achieved were below the level at which dispersion of the soil structure would be expected to occur.
3. Water infiltration rates were reduced during the year following high rates of applied manure; however, the infiltration rates recovered to nearly the level of the untreated soil within one year following cessation of waste application.
4. Runoff waters were not significantly affected by waste rates two years following application. Precipitation was insufficient to produce runoff earlier.

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SECTION 3

RECOMMENDATIONS

Wastes from cattle feedlots can be both a source of nutrients and organic matter for growing crops or a source of chemicals which pollute waters and salinize soils in the environment.

The following recommendations assume that the land upon which wastes are being applied is to be used for crop production:

1. Development of best management practices for applying wastes to the land should account for soil properties, chemical composition of the wastes, availability of leaching waters and the crop to be grown.
2. Incorporation of manure applied to the land reduces the opportunity for pollution of surface waters and utilizes the large buffering capacity of the soil to reduce chemical effects.
3. Availability of rainfall or irrigation water will influence crop response to added nutrients and will influence leaching of salts from the soil. Drought conditions reduce the fertilizer value of manure for crop production and increase salinity build-up within the soil.
4. Since the major annual runoff from cropland in the Northern Great Plains occurs at the time of melting of the winter snowpack, management of manure applied to the land so as to minimize the concentration during snowmelt should qualify as a best management practice.
5. Annual applications of manure in excess of 45 MT/ha should be avoided where the soil contains excess salts within 60 cm of the surface and where less than 20 inches of water is applied to the land as rainfall or irrigation.

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SECTION 4

BACKGROUND

Land application of animal waste is a disposal technique with both promise and problems. It offers a way to reverse the trend of mining plant nutrients and a method of returning organic matter to the soil, but the possibility of damaging the soil-water-plant system exists if necessary caution is not exercised in a land application program. The primary emphasis of this literature review will be land disposal of beef cattle wastes.

MANURE SALT CONSTITUENTS ADDED TO THE SOIL

Calcium (Ca), magnesium (Mg), sodium (Na), and potassium (K) ions and their salts are the most abundant chemical constituents in beef wastes and therefore exert the greatest influence on soils. Soil salinity is affected by the total concentration of these salts. The proportion of Ca, Mg, Na, and K adsorbed on soil clays plus the concentration of the soil solution influence soil structure. The electrical conductivity (EC) of soil saturation extracts and saturated pastes are measures of total soil salinity that have been correlated with crop yields. The conductivity of an electrolyte is the sum of the contributions of all the ionic species in the electrolyte (Daniel, 75). Since EC is a function of total concentration it is to be expected that EC values measured in soil will vary with the amount of salt originally present, the amount added in the manure, and the amount removed either by growing plants or leaching water. Salts added vary with the ration fed and the amount of salts removed depends on the quantity of leaching water and the permeability of the soil.

Sukovaty (74) and Swanson (74) did not measure significant changes in the EC of saturation extracts on a Colo silty clay loam at application rates of 2.5 and 5.0 cm beef feedlot effluent per week. Wallingford (74) found a linear correlation between the EC of saturation extracts and cumulative applications of lagoon water. They attributed a decrease in corn yields at application rates of 26 and 46 cm/yr to soil salinity. In similar work, Wallingford (75) developed a linear correlation between four year cumulative application rates of manure ranging from 114 to 2750 MT/ha and the EC of saturation extracts of surface soils. Electrical conductivity values exceeding 10 mmhos/cm were recorded at spring samplings. Mathers (74) found the EC of soil pastes in the seed zone of soils receiving 112 MT manure/ha/yr or more to exceed 3 mmhos/cm; however, by the end of the growing season, irrigation water had leached the salts sufficiently to reduce the EC below 3 mmhos/cm at all rates less than 224 MT/ha/yr. Mathers (71) cited soil salinity as a contributing factor in early season growth depression in 1969

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on plots manured at 69 and 134 MT/ha/yr. Before seeding in 1970, irrigation water was applied and enough dilution occurred to prevent growth depression.

Bingham (70) physically divided the root zone of corn plants into three equal parts using wax lenses as dividers. The root zone compartments enabled them to selectively salinize thirds of the root zone with a sodium chloride (NaCl) solution whose EC measured 12 mmhos/cm. They reported that salinization of the entire root zone cut shoot growth by 30 percent. Water uptake was reduced from a saline zone, however, increased uptake from the remaining zones partially compensated for the reduction. Lunin (65) doing similar research with corn found that water uptake decreased with increasing salinity and ceased entirely when the EC of a zone reached 14-16 mmhos/cm. They also reported increased uptake from the non-saline portions and slightly depressed yields after salinization of 2/3 of the root zone.

Early growth depression of corn grown on land receiving waste application rates of 275 and 540 MT/ha/yr were attributed to soil salinity by Manges (71). Mathers (71) reported early growth depression of grain sorghum in 1969 at application rates of 67 and 134 MT/ha/yr which they attributed to soil salinity, but the plants recovered and there was no significant difference in final yields. Growth of sorghum on plots receiving 269 and 538 MT/ha/yr remained depressed and yields were less than 1/3 of check yields. A possible explanation for the reported differences is that plants grown on plots with the lower application rates were stunted but the roots were able to penetrate to a non-saline portion of the soil profile from which they were able to more easily extract water. However, sorghum grown on the plots receiving the larger applications was severely stunted and the roots were unable to penetrate to a non-saline stratum in time to equalize yields. Similar rationale may be used to explain the results of Mathers (74) who reported recovery of early growth depression on plots manured at rates of 112 and 224 MT/ha/yr but continued growth depression at higher application rates.

MANURE AS SOIL CONDITIONER

Increased yields as a consequence of manuring have not always been explainable on the basis of added fertility. Many authors have cited manure, by virtue of the large quantities of organic matter present, as a soil conditioner capable of making soil more friable and in general improving soil structure.

Mazurak (75) simulated rainfall and reported that the diameter of detached aggregates increased with higher manure application rates. A consequence of the larger aggregates was an increased water intake rate of some of the soils. Zwerman (72) also simulated rainfall and found that plots manured at a rate of 13.5 MT/ha/yr had 50 percent less runoff than unmanured plots. During equal intensity rainfalls, runoff and infiltration are inversely proportional; therefore, infiltration was increased by 50 percent. Williams (62) reported that application of manure at the rate of 67 MT/ha/yr made soils more stable to water movement and increased permeability.

Studying the effects of a long term manuring program on water intake rates, Mazurak (55) determined that manure applications of 27 MT/ha/yr caused the

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greatest water intake rate increases in continuously cropped corn. Intake rates at 10 and 120 minutes went from 7 to 16 cm/hr and from 0.5 to 6.8 cm/hr respectively. Tiarks (74) found manure applications of 360 MT/ha increased the hydraulic conductivity of disturbed soil five-fold. The hydraulic conductivities of undisturbed soils were reduced by the large application rate but were nearly equal to those of unmanured soils by the following spring.

Holliday (65) suggested that greater available soil moisture was a factor which might explain increased yield responses to manure applications during dry years. Salter (63) determined volumetric moisture contents of manured and unmanured soils between field capacity and wilting point and reported that volumetric moisture contents were greater for the manured soil. Manuring also increased available water content and greater relative amounts of water were released at low tensions in the manured soil. Salter (67) measured matric suctions under actively growing ryegrass and found a decrease in matric suctions under manured plots. Olsen (70) determined that gravimetric moisture contents at field capacity (0.1 atmospheres tension) increased directly with application rate except at rates exceeding 200 MT/ha where a reduction occurred which was attributed to the formation of a waxy substance which acted to repel water.

WATER TRANSPORT THROUGH MANURED AND SALT AFFECTED SOILS

To facilitate interpretation of soil permeability data, various researchers have divided permeability vs. time data into phases. Christiansen (47) working with saline and alkali soils defined three phases. During the first phase, permeability decreases to a minimum below the initial rate due to the removal of salts and swelling of soils reducing the effective pore size. An increase in permeability, usually to a level higher than the initial rate, occurs during the second phase as trapped air gradually goes into solution. Soil sealing caused by microbial activity decreases permeability in phase three. Christiansen (47) reported that when sufficient gypsum was present to replace exchangeable Na with Ca little or no sealing took place during phase one. Thomas (66) gave coating of soil particles by phosphorus (P) and iron (Fe) which reduced pore size and plugging of soil pores by organic matter as possible explanations for the reductions in infiltration rate they observed during a sewage spreading experiment. Infiltration rates increased after sewage applications were discontinued and organic matter was the only soil constituent monitored that decreased during this period of time. According to Rice (74), chemical, physical, and biological factors cause soil clogging and reduced permeability. Chemical clogging is caused by an interaction between dissolved salts and soil particles resulting in smaller pores and consequently lower permeability. Physical clogging is the result of suspended solids blocking soil pores. When the soil pore size is greater than the diameter of the suspended solids some particles may penetrate to greater depths and build up a restrictive layer of low permeability. Biological clogging results when bacterial growth or the by-products of such growths reduce pore diameter. Biological clogging occurs only after long periods of inundation and usually occurs near the soil surface. Rice (74) concluded that decreases in permeability observed while flooding soil columns with secondary wastewater effluent were due to clogging of surface (0-1 cm) pores by suspended solids. DeVries (72)

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reported that failure of sand filters at low temperatures was caused by suspended solids clogging surface pores. Daniel (74) concluded that smaller particles could penetrate to form bottlenecks in the pore system and therefore the size of suspended solids influenced permeability. Lehman (75) found that a synthetic feedlot runoff reduced the infiltration rate of soil columns to less than 0.006 cm/hr. They concluded that clogging at or near the surface was responsible for the reduction because infiltration rates were increased by removing the upper 2 cm portion of the columns. Schuman (75) found potassium to be the predominant cation in the upper 15 cm of a feedlot soil. Columns of the feedlot soil sealed while being leached with a calcium chloride solution. This phenomenon was probably due to a 5-7 cm organic gel layer that formed on the soil surface.

Introduction of an electrolytic solution into a soil may cause the clays present to hydrate and swell decreasing pore size and permeability. Rowell (69) listed amount and type of clay present, exchangeable cations on the clay, free salt in the soil, concentration and composition of the electrolyte, and the presence of other materials in association with the clay such as sesquioxides and organic matter as factors controlling the swelling of soil. Hydrated sodium ions with their small charge to volume ratio and to a lesser extent other monovalent cations cause expandable clays to swell and if present in sufficient proportions to disperse entirely. Various researchers have set limits on the maximum exchangeable sodium percentage (ESP) allowable to maintain stable soil structure. United States Department of Agriculture (54) has set an ESP of 15 as the criteria for separating soils into non-alkali and alkali categories. Magistad (45) classified alkali soils, those likely to disperse as salts are leached, as those containing over 12 percent exchangeable sodium plus potassium. Emerson (67) classified soil aggregates on the basis of their coherence in water. Upon immersion of dry aggregates in water only those with an ESP of seven or more showed signs of dispersion.

Research by Quirk (55), McNeal (66), El-Swaify (67), and Hamid (75) reveals no particular basis for dividing soils into non-alkali and alkali classes at an ESP of 15. El-Swaify (67) used swelling pressure and water retention as measures of soil stability and found that swelling pressure and water retention of homoionic soils increased as electrolyte concentration decreased. These responses for sodium-calcium heteroionic soils took on linear relationships with the proportion of sodium on the soil complex. McNeal (66) and Quirk (55) measured hydraulic conductivity as a function of sodium adsorption ratio and electrolyte concentration. At a given electrolyte concentration, an increase in the sodium adsorption ratio of the percolating solution caused a decrease in hydraulic conductivity with no abrupt change at a sodium adsorption ratio corresponding to an ESP of 15. MaNeal (66) investigated seven typical agricultural soils of arid lands and reported that an ESP greater than 15 could be tolerated without serious reductions in hydraulic conductivity provided the salt concentration of percolating solutions exceeded three milliequivalents (meq)/l.

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Cross (73) associated decreases in hydraulic conductivity with the high sodium and potassium content of the percolating solution as a result of applied manure. Travis (71) measured lagoon water infiltration rates on

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soil columns and found that the infiltration rate was reduced to zero. The reduction was partially attributed to an imbalance of monovalent to divalent cations in the lagoon water. A simulated organic free lagoon water was used to test the theory on two soils. The infiltration rate of one of the soils went to zero; however, the infiltration rate of the other was increased with time. It is therefore likely that the organic matter in the lagoon water played a role in reducing infiltration rates.

When rain or irrigation water falls on a land surface at a rate exceeding the infiltration rate, the excess water can be expected to run off. Run-off waters can transport soil particles and amendments, such as manure, which become significant sources of pollution to the environment. Monitoring of runoff waters from land surfaces is important in evaluation of non-point pollution sources.

The literature reviewed shows that a given application rate of animal waste will not produce the same response on all soils. Manure composition, climate, soil texture and clay mineralogy are factors which influence the effects of animal waste on soil properties. For these reasons, waste disposal guidelines need to be flexible to meet local conditions.

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SECTION 5

METHODS AND MATERIALS

In the fall of 1973 16 pens with 11 steers in each pen were established at the Southeast South Dakota Experiment Farm. The steers were fed a common ration differing only in the amount of salt, sodium chloride (NaCl), added to the feed. The levels of added NaCl used during the feeding period were 0.00, 0.25, 0.50 and 0.75 percent of the ration on a dry weight basis.

The manure from these steers was collected and segregated into two salt levels: manure collected from animals fed 0.00 and 0.25 percent added NaCl, hereafter referred to as "low", and manure collected from animals fed 0.50 and 0.75 percent added NaCl, hereafter referred to as "high".

Manure was applied as soon after collection as practical to field plots with dimensions of 36.6 by 6.1 m established on Egan silty clay loam (Table 1) at the Southeast South Dakota Experiment Farm. The field design (Figure 1) was a randomized complete block including treatments of 0, 45, 90, 135 and 180 MT/ha/yr (check, 20, 40, 60, and 80 T/ac/yr) dry waste at both low and high salt levels. Manure applications were made during the period from harvest until spring tillage for 1973 until the 1975 growing season with no applications thereafter. At the time of application each load was weighed and a sample taken for water content and chemical analysis.

The chemical analyses included determinations for the cations Ca, Mg, Na, and K and water content. Calcium, Mg, Na, and K were determined by atomic adsorption (Issac, 71) on an extract obtained from dry waste by ashing a sample at 450° C, extracting with six normal solution of hydrochloric acid (HCl), and diluting to 100 ml with distilled water (Chapman, 61).

The fall-applied manure was incorporated with a chisel plow to approximately 15 cm. After the last waste was applied in the spring, all plots were moldboard plowed to turn over about 20 cm of soil. All plots were then disked and harrowed to establish a seedbed.

Plots manured at rates of 0, 45, and 90 MT/ha were planted on May 6 and 7, 1975. The plots receiving 135 and 180 MT manure/ha were too wet and "soft" at this time to allow machine traffic and were, therefore, planted on May 21, 1975. All plots were planted on May 6, 1976 and on May 10, 1977. The plots were planted to corn (*Zea mays* L.) at about 43,000 plants/ha with herbicide and insecticide applied in bands over the corn.

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Plant populations were determined on all plots by counting plants in 36.6 m of row on the dates indicated. Plant heights were determined by

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TABLE 1. DETAILED PROFILE DESCRIPTION OF THE EGAN SILTY CLAY LOAM SOIL (THIS IS AN APPROVED SOIL SERIES DESCRIPTION FROM THE STATE SOIL SCIENTIST'S OFFICE)

Location: Southeast Agricultural Experiment Farm, Centerville, South Dakota.

Classification: Typic Haplustoll; fine silty, mixed mesic.

Parent Material: Loess over glacial till.

Physiography: Nearly level plain with low broad ridges.

Salt or Alkali: None

Land Use: Cropland.

Stoniness: None above 68.6 cm (27 in).

Erosion: Slight.

Slope: 1 percent convex.

Permeability: Moderate.

Drainage: Well drained.

Ground Water: Deep.

Horizon	Depth cm	Description
Ap	0-17.8	Dark grayish brown (10YR 4/2) silty clay loam, very dark brown (10YR 2/2) moist; weak fine granular structure; soft, very friable, slightly sticky; slightly acid; abrupt smooth boundary.
B21	17.8-38.1	Brown (10YR 5/3) silty clay loam, very dark grayish brown (10YR 3/2) moist, crushing to dark brown (10YR 3/3), moist; weak medium prismatic structure; parting to weak coarse and medium subangular blocky structure; slightly hard, friable, slightly sticky; neutral; gradual wavy boundary.
B22	38.1-61.0	Grayish brown (2.5Y 5/2) silty clay loam, dark grayish brown (2.5Y 4/2) moist; weak coarse prismatic structure parting to weak coarse and medium subangular blocky structure; slightly hard, friable, slightly sticky; neutral; clear smooth boundary.
B3ca	61.0-78.7	Light brownish gray (2.5Y 6/2) silty clay loam, grayish brown (2.5Y 5/2) moist; common fine distinct strong brown (7.5YR 5/8) mottles; weak coarse subangular blocky structure; hard, friable, slightly sticky; common fine distinct accumulations; many medium soft lime segregations; strong

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TABLE 1 (continued)

Horizon	Depth cm	Description
		effervescence; moderately alkaline; gradual wavy boundary.
IIC1	78.7-106.7	Light brownish gray (2.5Y 6/2) clay loam, olive brown (2.5Y 4/4) moist; common fine distinct strong brown (7.5YR 5/8) mottles; moderate coarse prismatic structure parting to moderate coarse subangular blocky structure; hard, firm slightly sticky; common fine brown accumulations; many fine soft lime segregations; strong effervescence; moderately alkaline; gradual wavy boundary.
IIC2	106.7-152.4	Light brownish gray (2.5Y 6/2) clay loam, dark grayish brown (2.5Y 4/2) moist; many fine distinct strong brown (7.5YR 5/8) and yellowish red (5YR 4/8) mottles; moderate coarse subangular blocky structure; hard, firm slightly sticky; common fine and medium brown accumulations; common lime segregations; strong effervescence; strongly alkaline.

measuring every other plant for 36.6 m of row on the dates indicated.

Leaf samples were collected for plant analysis during the first week of August, 1975 and 1977. Leaves were taken from opposite and below ears which had silks white in color. The samples were dried at 90°C, ground with a stainless steel screen, and analyzed for Ca, Mg, Na and K plus micronutrients by spark-emission spectroscopy.

The corn was harvested as silage on September 11, 1975, and September 9, 1976, and August 29, 1977 by removing all the forage from a 13.9 m² section of each plot. The silage was weighed and a subsample taken for moisture determination after the forage passed through a chopper. Ear corn yields were determined on October 8, 1975, September 23, 1976 and September 28, 1977 by picking all the ears from a 13.9 m² section of each plot. All ears were weighed and moisture contents were determined on samples obtained from the mid-section of 12 ears. To minimize interference from crop residue all forage was removed from the plots after ear corn harvest.

Soils were sampled to a depth of 91.5 cm in 30.5 cm intervals with a standard power soil sampling probe on the dates indicated. Three samples were taken per plot and these were pooled to form one sample. The samples were permitted to air dry at least 72 hours before being mechanically ground and sieved through a two mm screen. Soil samples were analyzed for water

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66	20-L
67	40-L RO
68	80-L RO
69	60-L
70	80-L RO
71	80-H RO
72	C

Key

37-52 Plot number
H High NaCl treatment
L Low NaCl treatment
Size 36.6 x 6.1 m
RO Runoff collection

C Check
20 44.8 MT/ha/yr (20 T/ac/yr)
40 89.6 MT/ha/yr (40 T/ac/yr)
60 134.4 MT/ha/yr (60 T/ac/yr)
80 179.2 MT/ha/yr (80 T/ac/yr)

Figure 1. Field plot diagram for manure treatment study.

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soluble Ca, Mg, Na, and K, extractable Na and K, cation exchange capacity (CEC), EC, organic matter (OM), and pH. Water soluble Ca, Mg, Na, and K were obtained by analysis of the saturation extract (Wilcox, 65) with atomic adsorption analysis (Issac, 71). Extractable Na and K were determined by an atomic adsorption analysis (Issac, 71) of an ammonium acetate ($\text{NH}_4\text{C}_2\text{H}_3\text{O}_2$) extract (U.S. Department of Agriculture, 54). Cation exchange capacity (U.S. Department of Agriculture, 54) of the 0-30 cm depth was determined for the September 23, 1975 samples. Electrical conductivity (U.S. Department of Agriculture, 54) was determined for saturation extracts. A modified Walkley-Black procedure (South Dakota State University, 75) was used to determine soil OM and pH was measured on a saturated paste of soil.

The ability of water to infiltrate the soil was measured during the first two weeks of July, 1975 and the first two weeks of June, 1976. Water intake was measured in situ on one-half of the field plots. Double ring infiltrometer cylinders (Bertrand, 65) of 25.6 cm and 40.6 cm diameter were driven approximately 17 cm into the surface of the soil. The water delivery system consisted of recording rain gauges modified to continuously record accumulated infiltration through the inside cylinder. A constant head of approximately three cm was maintained in the inner ring during the test period with a self limiting vacuum system during 1975 and a small needle valve and float in 1976. The choice of three cm as a head was arbitrary, however, it should be mentioned that Rice (74), Baker (73), and Hardcastle (74) have reported more rapid reductions in permeability with greater hydraulic gradients.

Accumulated infiltration data was plotted, averaged, and regressed against time to develop regression equations. Accumulated infiltration was described by Taylor (72) using an empirical equation of the form:

$$i = ct^\alpha \quad (1)$$

where i = quantity of water per cross-sectional area ($1/\text{cm}^2$)

t = time (sec)

c and α = parameters which depend upon the soil physical condition.

This equation fits the data quite well for short periods of time, up to a few hours. Regression equations for the last part of the data were developed by regressing i against t in a polynomial regression subroutine. Infiltration rates were calculated by taking the first derivative of the regression equations at the desired times.

Seventeen plots, as identified in the plot diagram, Figure 1, were instrumented for measuring the quantity of runoff and for collecting samples for water quality analyses. The runoff plots slope gently in a northwesterly direction. An earth ridge was formed around each plot to divert runoff waters to a collection point. An H-type flume with a stilling well was installed in the ridge at the collection point. A horizontal drum water-stage recorder with float-activated clock was installed to measure runoff waters passing through the flume.

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A water collection reservoir was installed on the exit side of the flume to provide a pick-up volume for the automatic water sampler. The water sampler consisted of a pick-up tube, collection bottles, and a tripping mechanism that was activated by the stage recorder. Water was drawn into the collection bottles by a vacuum which had been established by evacuating the bottles using a vacuum pump. Water collected during a runoff event was transported within a few hours to the Water Quality Laboratory, South Dakota State University, for analyses.

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SECTION 6

RESULTS AND DISCUSSION

Actual amounts of manure applied to field treatments prior to the 1974 and 1975 growing seasons are given in Table 2. No additional manure was applied to any treatments following the 1975 season.

The results of the analysis of the waste for major cations appears in Table 3. While not literally correct, total cation concentration is taken to be the sum of the four major cations. In Table 3, it is shown that Na is the only salt constituent in the manure which varies to an appreciable extent with the NaCl level of the ration. Consequently, the amount of Na and total salts applied to field plots varied according to the amount of NaCl added to the ration.

Rainfall data for 1974 through 1977 are presented in Table 4. Total precipitation for 1975 and 1977 was approximately normal. Total precipitation for 1974 was 59 percent of normal and for 1976 was 50 percent of normal. Average or below average rainfall was recorded during June and July for all years of the study. The growing season of 1976 was one of the worst droughts on record for the region.

EC

A summary of the EC of the upper 30 cm of plot soils is shown in Table 5 for all years of the study. Detailed EC information including individual replicated plot values and accompanying statistical treatment for all plots to a depth of 150 cm is given in Appendix Tables A-1 through A-8.

The United States Department of Agriculture (54) gives an EC value of 4.0 mmhos/cm as the value separating non-saline from saline soils. Accepting the value for saline soils, it is apparent from the data presented in Table 5 that, given the limited rainfall during the study, two consecutive applications of manure exceeding 45 MT/ha/yr will supply sufficient salts to salinize the upper 30 cm of the soil profile. The data also indicate that, with the below normal rainfall, within two years after the end of treatment the upper 30 cm of all plots was leached sufficiently to be classed in the non-saline category.

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In addition to salinity of the surface soil, attention must be given to the salinity condition of the entire root zone as summarized in Table 6. Prior to onset of this investigation, the EC of all plots at a depth of 90 cm exceeded 4.0 mmhos/cm. The results show completely saline root zones after

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TABLE 2. MANURE APPLICATION RATES PRIOR TO 1974 AND 1975 GROWING SEASONS

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Treatment	1974 MT/ha*	1975 MT/ha*	Two year total MT/ha*
Check	0.0	0.0	0.0
45-L **	38.5	48.6	87.1
45-H +	26.9	50.8	77.7
90-L	101.5	92.5	194.0
90-H	85.3	92.3	177.7
135-L	135.2	138.0	273.2
135-H	119.7	139.6	259.3
180-L	169.6	181.8	351.3
180-H	172.7	182.9	355.6

* On a dry weight basis.
** L = low
+ H = high

TABLE 3. AVERAGE COMPOSITION OF MANURE APPLIED TO FIELD PLOTS PRIOR TO THE 1975 GROWING SEASON

	Low salt (%)*	High salt (%)*
Na	0.37	0.75
K	3.19	3.16
Ca	1.05	1.05
Mg	0.88	0.89
Total cations	5.49	5.85

* On a dry weight basis.

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TABLE 4. MONTHLY PRECIPITATION FOR SOUTHEAST SOUTH DAKOTA EXPERIMENT FARM

	1974 (cm)	Deviation from average 1974 (cm)	1975 (cm)	Deviation from average 1975 (cm)	1976 (cm)	Deviation from average 1976 (cm)	1977 (cm)	Deviation from average 1977 (cm)
January	0.51	- 0.76	4.09	+2.82	1.60	+ 0.33	0.33	-0.94
February	0.10	- 2.90	0.38	-2.62	2.31	- 0.69	0.84	-2.16
March	2.44	- 1.04	4.11	+0.64	2.36	- 1.12	6.99	+3.51
April	1.65	- 4.50	6.48	+0.33	5.77	- 0.38	6.65	+0.51
May	9.83	+ 0.99	5.84	-3.00	4.98	- 3.86	8.18	-0.66
June	7.87	- 4.06	11.94	0.00	3.33	- 8.61	8.79	-3.15
July	4.47	- 3.43	0.79	-7.11	4.55	- 3.35	9.80	+1.91
August	6.25	- 1.47	17.02	+9.30	2.67	- 5.05	6.60	-1.12
September	2.39	- 4.42	6.88	+0.08	2.90	- 3.91	10.16	+3.35
October	2.64	- 1.55	0.71	-3.48	1.45	- 2.74	4.78	+0.58
November	0.46	- 1.93	6.96	+4.57	0.13	- 2.26	3.40	+1.02
December	0.10	- 1.47	0.18	-1.40	0.53	- 1.04	1.60	+0.03
Total	38.71	-26.54	65.38	+0.13	32.58	-32.68	68.12	+2.88

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TABLE 5. AVERAGE ELECTRICAL CONDUCTIVITY OF THE SATURATION EXTRACTS FOR THE SURFACE 30 CM OF PLOT SOILS

Treatment (MT/ha)	Fall 1973 (mmhos/cm)	Fall 1974 (mmhos/cm)	Fall 1975 (mmhos/cm)	Fall 1976 (mmhos/cm)	Fall 1977 (mmhos/cm)
Check	0.70	1.12	1.30	1.67	1.15
45-L *	0.68	2.42	4.52	3.04	1.28
45-H +	0.46	1.93	3.73	3.46	2.04
90-L	0.72	4.87	5.39	6.36	1.84
90-H	0.71	3.96	5.96	4.92	2.11
135-L	0.68	5.89	7.80	6.19	2.87
135-H	0.74	5.46	7.14	5.79	2.25
180-L	0.92	4.90	7.23	5.84	3.29
180-H	0.83	6.02	8.84	6.06	3.08
Mean	0.72	4.06	5.77	4.81	2.21

* L = low
+ H = high

two yearly applications of manure at a rate of 90 MT/ha/yr or greater.

ESP, EPP

Exchangeable sodium percentage (ESP) and exchangeable potassium percentage (EPP) of surface soils are presented in Table 7. Concern has been expressed that Na added to the soil by the manure treatments may cause an increase in ESP to levels which constitute a dispersion hazard. Despite rather large yearly Na applications, the ESP of plot soils remained below 3 percent. The Ca and Mg added with the manure plus that native to the soil are sufficient to maintain a low ESP for these soils. A simple linear regression with ESP the dependent variable and cumulative weight of applied Na the independent variable yields the following equation:

$$ESP = 0.72 + 6.17 \times 10^{-4} Na \quad (2)$$

where Na = applied sodium (kg/ha)
 $r^2 = 0.84$

which indicates that weight of added Na explains a large part of the variability in ESP for the fall of 1975. The ESP data also show a marked

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TABLE 6. ELECTRICAL CONDUCTIVITY OF THE SUBSURFACE SOIL FOLLOWING TREATMENT

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Year and treatment	30-60 cm mmhos/cm	60-90 cm mmhos/cm	90-150 cm mmhos/cm
<u>1974</u>			
Check	2.45	4.01	5.51
45-L*	1.28	3.65	5.68
45-H ⁺	0.64	4.47	5.92
90-L	1.58	4.89	6.15
90-H	1.41	4.08	5.36
135-L	1.51	4.95	5.85
135-H	1.71	4.20	5.72
180-L	2.29	4.95	6.31
180-H	1.90	4.57	5.78
<u>1975</u>			
Check	3.05	4.28	----
45-L	2.39	3.57	----
45-H	2.10	2.37	----
90-L	4.07	4.38	----
90-H	4.09	4.29	----
135-L	4.67	5.55	----
135-H	4.94	3.73	----
180-L	4.96	5.34	----
180-H	5.05	4.83	----

* L = low
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TABLE 7. AVERAGE CATION EXCHANGE CAPACITY, EXCHANGEABLE SODIUM PERCENTAGE, AND EXCHANGEABLE POTASSIUM PERCENTAGE, 0-30 CM PROFILE DEPTH

Treatment	CEC meq/100g	Fall 1975		Σ %	Spring 1976		
		ESP %	EPP %		ESP %	EPP %	Σ %
Check	30.42	0.43	2.43	2.86	0.39	2.89	3.28
45-L*	29.26	0.75	6.22	6.97	0.72	6.02	6.74
45-H ⁺	29.66	1.28	5.77	7.05	0.91	4.08	4.99
90-L	31.76	0.94	9.38	10.32	0.85	12.09	12.94
90-H	31.28	1.82	10.23	12.05	1.21	10.87	12.08
135-L	32.87	2.07	11.74	13.81	0.70	13.69	14.39
135-H	33.61	2.62	13.03	15.65	1.49	15.26	16.75
180-L	31.01	1.39	21.35	22.74	1.29	15.80	17.09
180-H	31.82	2.48	21.68	24.16	1.60	18.20	19.80

* L = low
+ H = high

reduction in the upper 30 cm for the higher application rate treatments after applications had been discontinued for one year as indicated by spring 1976 data.

Table 7 shows a pronounced increase in EPP as a result of the high K content of the applied manure. Changes in EPP were erratic after termination of applications which may indicate the presence of K fixing micaceous or illitic clay minerals in the soil.

Soil determinations of Na content and sodium adsorption ratios (SAR) for all depths, treatments and years are reported with accompanying statistical analyses in Appendix Tables A-9 through A-20. Manure treatments produced mostly non-significant changes in Na levels below 60 cm for the period of the study.

WATER INFILTRATION

The soil's ability to allow water to infiltrate was measured to determine if the rates of manure applied to the field plots were causing a breakdown in soil structure. Accumulated infiltration data are presented in graphical form in Figures 2, 3, 4, and 5. Infiltration rates were

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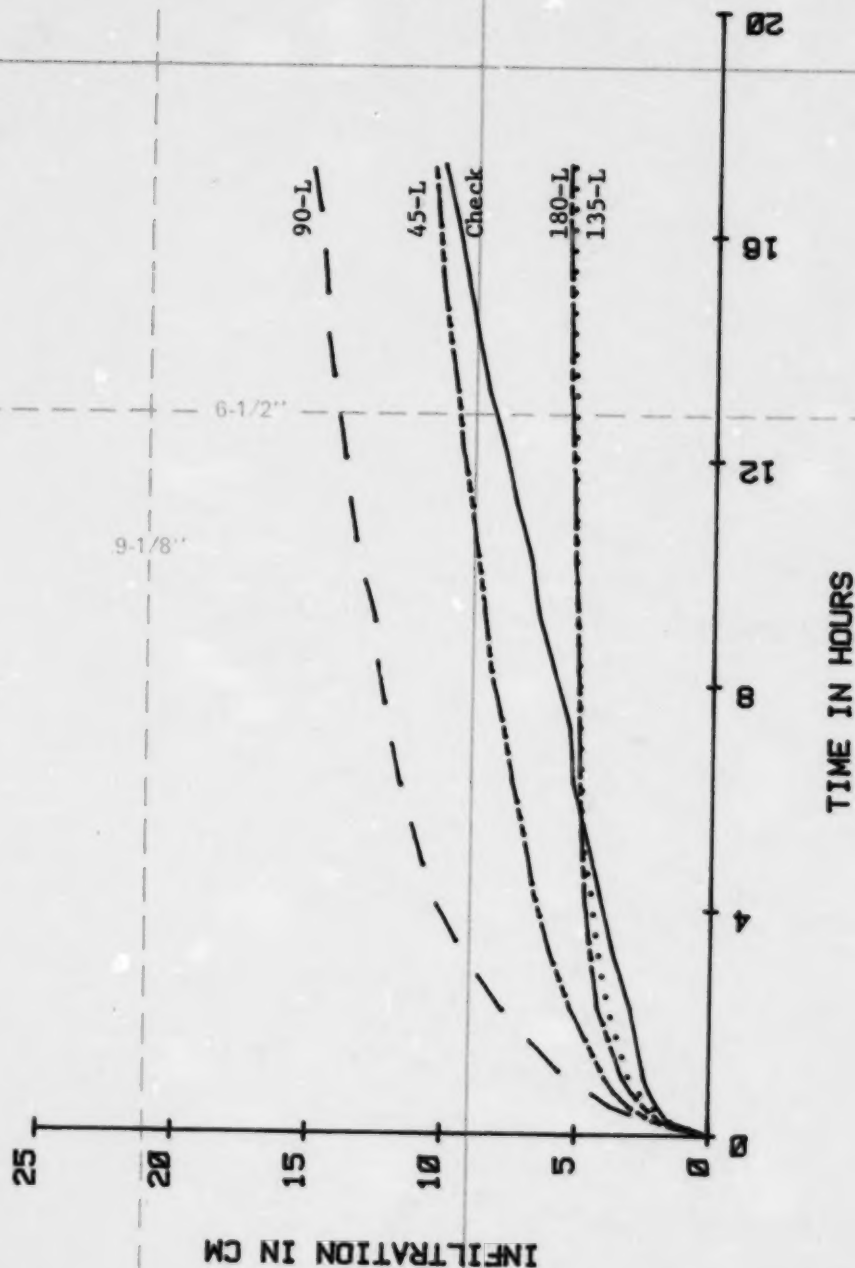


Figure 2. Accumulated water infiltration into plots receiving low salt manure treatments (1975 data).

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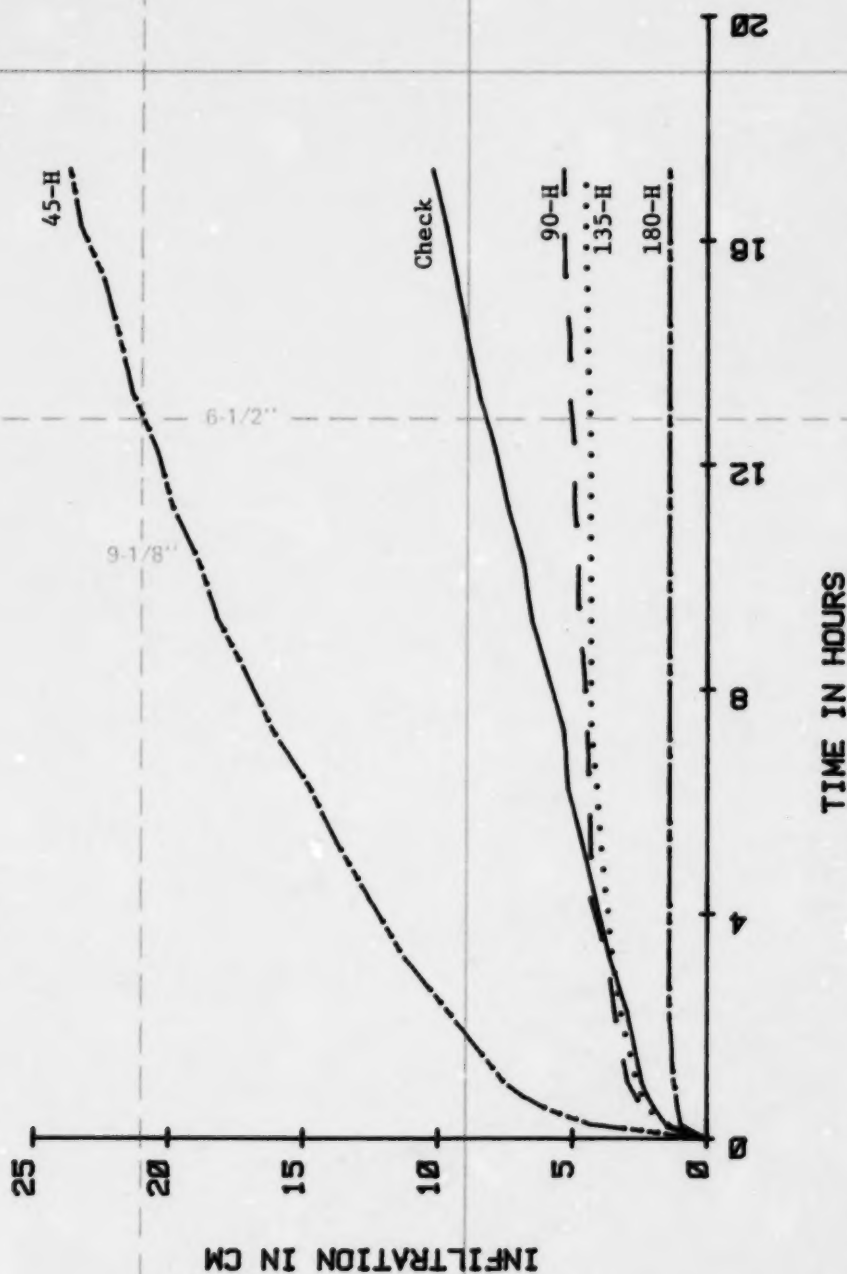


Figure 3. Accumulated water infiltration into plots receiving high salt manure treatments (1975 data).

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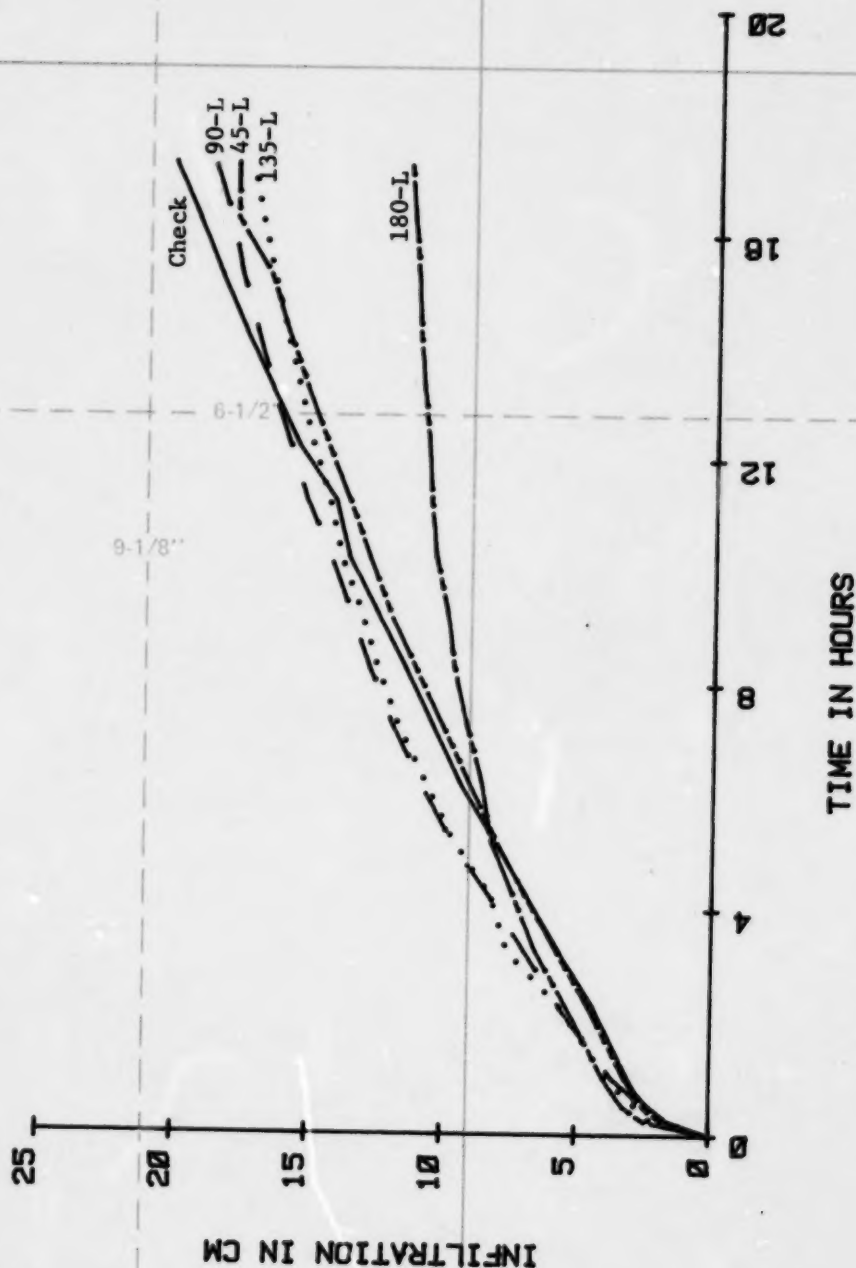


Figure 4. Accumulated water infiltration into plots receiving low salt manure treatments (1976 data).

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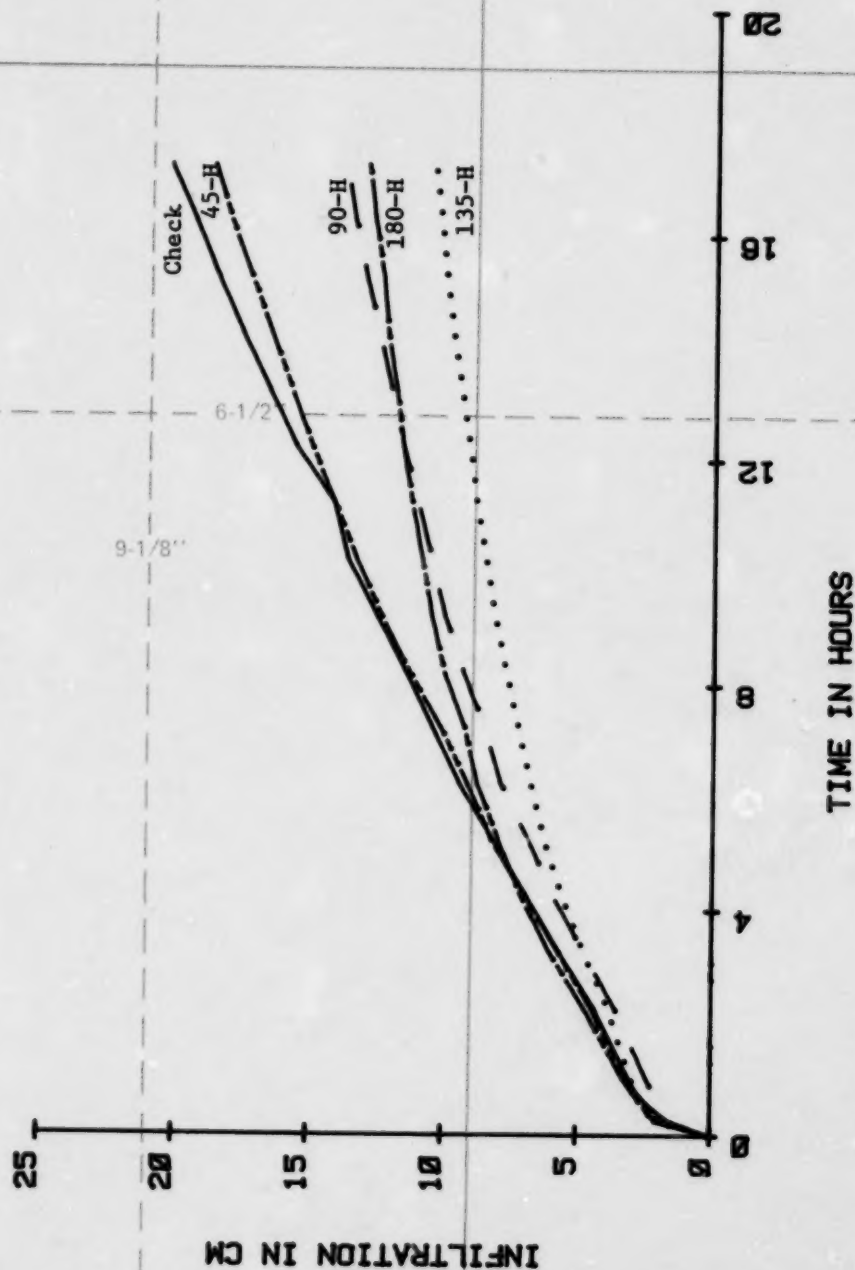


Figure 5. Accumulated water infiltration into plots receiving high salt manure treatments (1976 data).

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calculated using the regression equations of the accumulated infiltration data. A ratio of accumulated infiltration at one hour to accumulated infiltration at 12 hours was calculated for comparative purposes and is referred to as the water stability ratio (WSR). A smaller WSR is indicative of greater stability of the soil to water movement through it. Addition of water and dilution of the soil solution with the consequent thickening of the electric double layer of the clay may cause the soil to swell and disperse if the percentage of monovalent cations on the exchange complex is high and the solution is sufficiently dilute. Swelling and dispersion of the soil would reduce infiltration and increase WSR. Washing organic or inorganic particles through the pore system to a zone of smaller diameter pores, such as plow sole, where the particles can accumulate and build up a restrictive layer would also cause a larger WSR.

Water stability ratios for 1975 and 1976 are given in Table 8. Manure application rate had a marked effect on water infiltration in 1975 with the higher rates reducing infiltration. Infiltration differences measured in 1975 were in large part eliminated by 1976 after discontinuation of the applications for one year. The results of the analysis of variance for WSR are presented in Appendix Table B-1. The results show the effect of waste rate on WSR to be significant at the 95 percent level for 1975 and 1976. Dunnet's test indicates that the WSR of the 135 and 180 MT/ha/yr treatments were significantly different from the check treatments at the 95 percent level in 1975 and at the 99 percent level in 1976.

Causes for the measured effect of waste rate on infiltration may be difficult to establish. From the literature review, it was found that a variety of possibilities exist. Among them are the following: 1) surface sealing by organic matter, 2) dispersion by Na, 3) dispersion by an imbalance of monovalent to divalent cations on the exchange complex, 4) organic gel formation, and 5) plugging of soil pores by organic matter particles.

Surface sealing may be eliminated as a probable cause, since, due to the dryness of the soil at the time the tests were performed, the soil contained cracks. To prevent lateral movement of water out of the infiltrometer cylinders, it was necessary to drive them into the soil to a depth of approximately 17 cm.

Sodium dispersion of the soil is an inherently attractive cause for reduced infiltration since Na content of the manure is a major factor in this investigation. The observation that ESP and WSR data follow the same general pattern, particularly for the higher application rates, may lead one to give ESP a major role in water intake reductions. It should be noted that the highest ESP recorded in Table 7 is 2.62. There is little, if any, evidence to suggest Na dispersion of this soil with an ESP of 2.62 or less, particularly in light of the total amount of salts present in the soil.

A look at the EPP values in Table 7 reveals values in excess of 20. Studies on the dispersion effects of Na and K do not give a clear picture of the dispersion potential of K. If K is given an equal status with Na and a critical value of 15 is accepted as the exchangeable monovalent cation

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TABLE 8. AVERAGE WATER STABILITY RATIO

Treatment	1975	1976
Check	0.33	0.19
45-L*	0.40	0.21
45-H†	0.37	0.22
90-L	0.35	0.24
90-H	0.68	0.25
135-L	0.61	0.28
135-H	0.87	0.37
180-L	0.79	0.38
180-H	0.87	0.32

* L = low
† H = high

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percentage which represents a dispersion hazard, the plots which received 135 MT/ha/yr or more fall into the dispersion hazard category due to their ESP + EPP values. Examination of results for the 90 and 135 MT/ha/yr treatments shows an increase in EPP and ESP + EPP from the fall of 1975 to the spring of 1976. Water infiltration results for the same treatments show an improvement in the absolute WSR values as well as WSR of these treatments relative to the check treatment. This makes it unlikely that an imbalance of monovalent to divalent cations in the exchange complex is the sole cause of treatment effects on water intake.

Organic matter data for the 0-30 cm soil depth are presented in Table 9. The increased organic matter resulting from manure treatments provides a source of organic materials for plugging of soil pores.

No direct visual examinations of the pore systems were made with a scanning electron microscope or other methods. It is therefore difficult to partition the water intake capability changes of this soil into categories of decreased pore size as a result of soil swelling and pore plugging by organic or inorganic particles.

It is unlikely that a single factor is responsible for the entire intake capability changes resulting from the treatments employed during this study. It is more likely an interaction of some soil swelling caused by the high ESP + EPP of the soils and physical plugging of soil pores by the large quantities of added organic matter.

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TABLE 9. AVERAGE ORGANIC MATTER CONTENT OF THE 0-30 CM PROFILE DEPTH

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Treatment	Fall 1974 (%)	Fall 1975 (%)
Check	2.87	2.95
45-L*	2.95	3.17
45-H+	3.02	3.15
90-L	3.50	3.67
90-H	3.30	3.67
135-L	3.67	4.32
135-H	3.62	3.80
180-L	3.52	4.35
180-H	3.32	4.50

* L = low
+ H = high

RUNOFF WATERS

Due to below average rainfall, runoff waters occurred from the plots on only two occasions--June 22, 1977, and March 20, 1978. The automatic sampling equipment collected runoff waters from only four treatments--90-L, 90-H, 180-L and 180-H--in 1977. Runoff waters were collected manually from all plots in 1978.

Results of the chemical analyses of runoff waters are shown in Tables 10 and 11. Complete results are given in Appendix Tables B-2 and B-3. The results were quite variable with little significant differences between the check and treatment plots except for chloride ions. Incorporation of the manure into the soil apparently protected runoff waters from contamination due to waste treatments.

PLANT PERFORMANCE

Plant population data are given in Table 12 and Appendix Tables C-1 and C-2. Populations were significantly different at the 99 percent level for treatments and years. Manure application rates in excess of 45 MT/ha/yr resulted in reduced populations when compared with the check.

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TABLE 10. CHEMICAL DATA FOR RUNOFF WATERS COLLECTED JUNE 22, 1977 FROM PLOTS SHOWN

Constituent	Units	90-L*	90-H†	180-L	180-H
Ca	ppm	7.40	5.85	3.50	5.63
Mg	"	2.50	2.54	3.50	2.00
Na	"	1.20	1.99	1.10	1.50
K	"	7.75	7.24	18.10	8.73
NO ₃ -N	"	0.66	0.51	0.94	0.80
Cl	"	0.95	2.65	2.00	1.68
pH	---	7.18	7.38	6.58	6.99
EC	umhos/cm	68.10	71.14	82.50	61.88
P	ppm	5.84	5.80	9.50	8.07
N	"	0.87	0.97	1.07	1.36
TS	"	125.00	171.34	158.00	130.00
DS	"	71.40	114.73	92.00	71.00
SS	"	29.20	31.50	34.00	33.50
VS	"	38.20	97.00	---	53.00
BOD	"	5.30	8.00	5.00	6.25
COD	"	23.50	20.30	41.00	56.50

* L = low
† H = high

Plant height data for 1975 and 1976 are presented in Figures 6 and 7. Statistical analysis of height data showed significant differences in plant height among waste rates at the 99 percent level for all sampling dates except July 21, 1976. Plant heights on plots receiving wastes at rates of 135 MT/ha/yr or more were significantly different from check height at the 99 percent level on June 27, 1975. The height of plants on plots manured at rates of 90 MT/ha/yr or more were significantly different from check heights at the 99 percent level on July 7, 1975, June 10, 1976, and June 22, 1976.

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TABLE 11. CHEMICAL DATA FOR RUNOFF WATERS COLLECTED MARCH 20, 1978

Units	Ck	45-L*	45-H+	90-L	90-H	135-L	135-H	180-L	180-H
Ca	11.00	13.00	12.00	8.00	9.00	8.00	15.00	11.00	9.00
Mg	9.00	9.00	8.00	7.00	6.00	8.00	7.00	12.00	6.00
Na	0.20	0.20	0.38	0.40	0.40	0.43	0.53	0.60	0.73
K	9.00	10.00	10.00	15.00	15.00	16.00	14.00	22.00	19.00
NO ₃ -N	1.02	0.60	0.85	0.72	0.85	0.68	1.01	1.32	0.57
Cl	2.13	2.50	3.00	2.95	4.40	2.63	2.95	3.25	3.08
pH	7.09	7.09	7.13	7.10	7.13	7.15	7.18	7.11	7.12
EC	114.00	105.00	117.00	123.00	119.00	112.00	118.00	144.00	126.00
P	1.64	2.62	2.53	5.67	4.16	7.30	3.87	12.39	9.22
N	1.40	2.06	2.24	1.83	1.70	2.65	2.01	2.05	2.21
TS	92.00	90.00	115.00	126.00	112.00	129.00	126.00	150.00	105.00
DS	76.00	93.00	88.00	84.00	100.00	130.00	143.00	134.00	88.00
SS	5.00	21.00	11.00	26.00	5.00	47.00	74.00	8.00	11.00
VS	34.00	30.00	56.00	29.00	39.00	45.00	45.00	35.00	29.00
BOD	7.00	7.00	6.00	9.00	9.00	9.00	7.00	9.00	10.00
COD	18.00	19.00	19.00	29.00	21.00	25.00	28.00	42.00	27.00

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* L = low
H = high

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TABLE 12. AVERAGE PLANT POPULATIONS				
Treatment	1974 (plants/ha)	1975 (plants/ha)	1976 (plants/ha)	1977 (plants/ha)
Check	49,511	34,351	40,364	33,463
45-L*	48,435	34,890	39,018	33,463
45-H+	48,436	34,620	40,274	32,150
90-L	40,902	31,660	37,135	31,494
90-H	45,206	28,791	38,301	34,119
135-L	39,826	28,611	35,969	31,494
135-H	38,210	28,702	38,032	32,807
180-L	36,596	29,866	37,942	34,119
180-H	30,676	28,818	36,058	32,807
Mean	41,977	30,756	38,151	32,879

* L = low
+ H = high

One of the reasons for collecting the plant height data was to test the idea that satisfactory plant growth could be attained on saline soils if a portion of the root zone was maintained in a non-saline condition. A corollary being that, despite early growth depression, if plant roots were able to penetrate to a non-saline portion of the soil profile, the plants could recover and attain yields equal to plants grown on non-saline soil. Conversely, if the soil were non-saline and roots penetrated into a saline portion of the profile the growth of plants would fall behind that of plants grown on entirely non-saline soil. Collection of good data and straightforward interpretation of the data were hampered by below normal rainfall which caused early drought stress and provided conditions favorable for smut disease in 1975. Corn borer damage affected crop growth and yield in 1976.

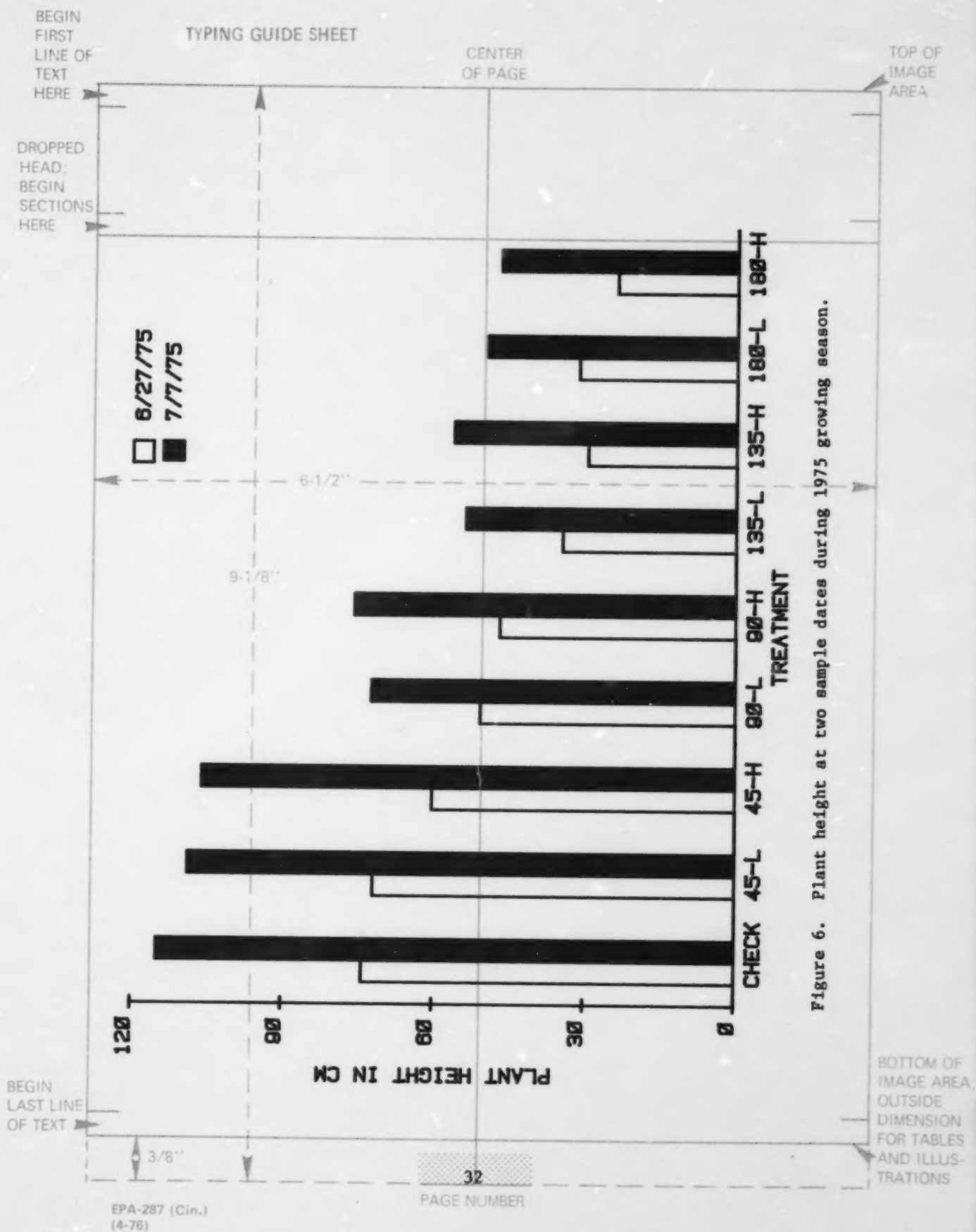
The results of a corn borer damage survey conducted on July 21, 1976 are presented in Table 13. The greatest infestation of European corn borer occurred in plots with a history of low or no applications of manure. There was a significant difference in total number of burrows among waste rates at the 95 percent level. Visual observations indicated that corn smut and weed density followed the pattern set by the corn borer data. The problems were of greater magnitude on plots with low accumulated applications. Two possible reasons for these observations come to mind: 1) that the causative

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PLANT HEIGHT IN CM

CHECK 45-L 45-H 90-L 90-H 135-L 135-H 180-L 180-H
TREATMENT

Figure 7. Plant height at three sample dates during 1976 growing season.

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TABLE 13. CORN BORER DAMAGE SURVEY 7-21-76

Treatment	Larvae	Pupae	Burrows	Undamaged stalks
	No./16 stalks			
Check	6	17	32	3
45-L*	3	19	33	2
45-H ⁺	1	18	25	2
90-L	0	17	23	2
90-H	3	6	14	7
135-L	1	9	11	8
135-H	1	5	9	10
180-L	1	7	11	8
180-H	0	3	6	12

* L = low
+ H = high

organisms were salt sensitive or unable to obtain sufficient moisture to remain vigorous, and 2) the chemicals used to control insects, weeds, and disease were moisture activated. Better chemical control would be expected on high application plots if the causative organisms were salt sensitive due to the higher osmotic potential of water in these plots and also if moisture activation of the chemicals were required for control since those plots had a greater gravimetric moisture content when they were sampled at the time the infiltration tests were performed.

An imbalance of K/Ca+Mg in forage fed to ruminants may cause a potentially fatal condition known as hypomagnesia. Corn leaf sample K/Ca+Mg ratios appear in Table 14. If 2.2 (Thill, 75) is taken as a value of K/Ca+Mg above which chances of hypomagnesia increase greatly and these ratios persist until harvest, nearly all of the forage produced on these plots is potentially toxic. An additional year of waste application did not aggravate the potential for hypomagnesia occurrences in ruminants fed forage produced on these plots. Significant differences at the 95 percent level were measured in Mg of leaf samples among waste rates and in Ca between salt levels. There was a significant difference in Ca content among waste rates at the 99 percent level. No significant differences in K content was detected between salt levels nor among waste rates. The differences in K/Ca+Mg rates do not appear to result from "luxury" consumption of

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TABLE 14. K/CA+MG VALUES OF CORN LEAF SAMPLES

Treatment	K/Ca+Mg	
	1974*	1975
Check	2.42	2.11
45-L**	2.85	2.13
45-H ⁺	2.61	2.21
90-L	2.97	2.81
90-H	3.09	2.52
135-L	3.28	3.68
135-H	3.21	2.99
180-L	3.42	3.80
180-H	3.53	3.14

* J. L. Halbeisen (1975)
** L = low
+ H = high

K but rather from decreased plant uptake of Ca and Mg as application rates increase.

Silage yields are reported in Table 15 and in Appendix Tables C-3 and C-4. Although years and treatments were significant in the analysis of variance, comparison of treatments with the check gave significance primarily where more than 135 MT/ha (60 t/a) of manure were applied.

Ear corn yields are reported in Table 16 and in Appendix Tables C-5 and C-6. Time of application of manure (years) and rates of application were significant at the 99 percent level in the analysis of variance; however, when treatments were contrasted against the check, almost no significance was found. Interaction between treatments and years was also significant. Silage and ear corn yields were highly influenced by the weather conditions which varied from excellent rainfall to extreme drought.

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TABLE 15. AVERAGE SILAGE YIELDS

Treatment	1974 MT/ha	1975 MT/ha	1976 MT/ha	1977 MT/ha
Check	5.67	7.95	2.83	8.93
45-L*	8.47	8.00	3.07	9.60
45-H ⁺	6.72	8.08	2.77	9.84
90-L	7.54	6.98	3.07	8.51
90-H	7.86	5.11	3.52	8.32
135-L	5.98	5.26	3.37	7.14
135-H	6.68	3.60	3.75	7.47
180-L	7.68	5.65	3.66	7.59
180-H	6.37	3.86	3.54	6.85
Mean	7.00	6.05	3.29	8.25

* L = low
+ H = high

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TABLE 16. AVERAGE EAR CORN YIELDS

Treatment	1974 MT/ha	1975 MT/ha	1976 MT/ha	1977 MT/ha
Check	1.42	1.40	0.16	5.41
45-L*	1.99	2.26	0.15	5.15
45-H ⁺	1.27	2.28	0.26	4.87
90-L	2.25	2.68	0.24	3.89
90-H	1.97	2.45	0.37	4.28
135-L	1.91	1.57	0.62	4.03
135-H	2.20	1.69	0.63	3.87
180-L	2.24	1.97	0.40	3.27
180-H	1.97	0.79	0.51	3.12
Mean	1.91	1.90	0.37	4.21

* L = low
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APPENDIX A

PLOT SOIL CHEMICAL DATA AND STATISTICAL TREATMENT

Chemical analysis data for soil in all treatment plots for specified depth increments are given. Statistical analysis of variance results are given where determined.

Electrical conductivity of 0-30 cm soil depth	(Table A-1)
Analysis of variance--EC 0-30 cm soil depth	(Table A-2)
Electrical conductivity of 30-60 cm soil depth	(Table A-3)
Analysis of variance--EC 30-60 cm soil depth	(Table A-4)
Electrical conductivity of 60-90 cm soil depth	(Table A-5)
Analysis of variance--EC 60-90 cm soil depth	(Table A-6)
Electrical conductivity of 90-150 cm soil depth	(Table A-7)
Analysis of variance--EC 90-150 cm soil depth	(Table A-8)
Sodium content 0-30 cm soil depth	(Table A-9)
Analysis of variance--Na 0-30 cm soil depth	(Table A-10)
Sodium content 30-60 soil depth	(Table A-11)
Analysis of variance--Na 30-60 cm soil depth	(Table A-12)
Sodium content 60-90 cm soil depth	(Table A-13)
Analysis of variance--Na 60-90 cm soil depth	(Table A-14)
Sodium content 90-150 cm soil depth	(Table A-15)
Analysis of variance--Na 90-150 cm soil depth	(Table A-16)
Sodium adsorption ratio for all soil depths	(Tables A-17 through A-20)

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TABLE A-1. ELECTRICAL CONDUCTIVITY (MMHOS/CM) OF 0-30 CM SOIL DEPTH

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	CK	45-L†	45-H§	90-L	90-H	135-L	135-H	180-L	180-H
<u>Fall 1977</u>									
*R1	1.28	1.33	2.38	2.03	1.84	2.96	2.81	2.57	2.68
*R2	0.56	1.33	0.99	1.13	1.64	2.20	1.55	2.75	2.81
*R3	1.62	1.30	2.71	1.49	3.53	3.39	2.81	3.29	2.75
*R4	1.13	1.18	2.07	2.70	1.41	2.93	1.82	4.55	4.09
+ $\bar{x}$	1.15	1.28	2.04	1.84	2.11	2.87	2.25	3.29	3.08
<u>Spring 1977</u>									
R1	1.69	3.05	2.31	2.92	5.68	5.94	3.84	5.22	5.56
R2	2.69	3.01	3.32	3.57	3.22	2.05	4.88	7.94	11.65
R3	2.05	2.19	2.40	2.88	3.63	5.46	4.68	2.53	5.25
R4	3.29	2.83	3.53	5.44	4.07	4.88	6.11	6.27	6.16
$\bar{x}$	2.43	2.77	2.89	3.70	4.15	4.59	4.88	5.49	7.16
<u>Fall 1976</u>									
R1	1.42	3.10	3.13	3.82	7.33	4.90	5.81	5.67	6.01
R2	1.67	4.39	4.30	2.83	3.18	4.77	4.95	4.84	4.84
R3	1.29	2.03	1.85	8.57	4.15	9.68	6.29	4.55	5.32
R4	2.30	2.65	4.56	10.23	5.02	5.42	6.12	8.29	8.09
$\bar{x}$	1.67	3.04	3.46	6.36	4.92	6.19	5.79	5.84	6.06
<u>Fall 1975</u>									
R1	0.63	3.09	3.37	6.50	6.52	7.54	6.63	8.11	8.09
R2	1.25	5.47	4.08	6.07	4.59	6.54	7.44	6.86	7.13
R3	0.67	5.97	3.34	3.62	6.34	9.81	6.48	6.26	9.39
R4	2.67	3.55	4.12	5.37	6.39	7.33	8.01	7.68	10.77
$\bar{x}$	1.30	4.52	3.73	5.39	5.96	7.80	7.14	7.23	8.84
<u>Fall 1974</u>									
R1	0.59	2.32	1.55	4.80	4.58	7.55	5.36	3.83	5.86
R2	0.71	3.53	2.21	3.28	3.09	3.95	5.30	5.41	6.51
R3	0.72	0.56	0.65	3.91	3.61	5.54	5.47	4.87	6.52
R4	2.45	3.26	3.31	7.50	4.55	6.50	5.70	5.50	5.18
$\bar{x}$	1.12	2.42	1.93	4.87	3.96	5.89	5.46	4.90	6.02
<u>Fall 1973</u>									
R1	0.46	0.77	0.56	0.79	0.58	0.44	0.51	0.55	0.55
R2	0.68	0.65	0.54	0.54	0.48	0.88	0.63	1.47	0.45
R3	0.80	0.55	0.06	0.82	0.95	0.62	0.76	0.61	1.69
R4	0.84	0.76	0.68	0.75	0.84	0.80	1.05	1.06	0.63
$\bar{x}$	0.70	0.68	0.47	0.72	0.71	0.68	0.74	0.92	0.83

† L = low

§ H = high

* R1-R4 = data for replications 1 through 4

+ $\bar{x}$ = average of four replications

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TABLE A-2. ANALYSIS OF VARIANCE -- EC 0-30 CM SOIL DEPTH

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Source	DF ⁺	SS ⁺⁺	MS ⁺	F ⁺⁺
Row	5.00	612.83	122.57	84.00**
Column	8.00	321.41	40.18	27.53**
Interaction	40.00	140.20	3.50	2.40**
Error	162.00	263.39	1.46	
Total	215.00	--		

Row Contrasts	NUM DF [§]	DEN DF ^{§§}	F
1973 vs F1977	1.00	162.00	41.33**
1973 vs S1977	1.00	162.00	228.14**
1973 vs 1976	1.00	162.00	310.82**
1973 vs 1975	1.00	162.00	472.25**
1973 vs 1974	1.00	162.00	207.05**

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Column Contrasts	NUM DF	DEN DF	F
CK vs 45L	1.00	162.0	9.23**
CK vs 45H	1.00	162.0	8.61**
CK vs 90L	1.00	162.0	48.18**
CK vs 90H	1.00	162.0	41.28**
CK vs 135L	1.00	162.0	88.27**
CK vs 135H	1.00	162.0	73.12**
CK vs 180L	1.00	162.0	85.10**
CK vs 180H	1.00	162.0	127.59**
High vs Low	1.00	162.0	0.09NS#

9-1/8"

+ DF = degrees of freedom
 ++ SS = sum of squares
 + MS = mean square
 ++ F = tabular F
 § NUM = numerator
 §§ DEN = denominator
 ** F.01 = 6.63 significant at the 99 percent probability level
 # NS = non-significant

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TABLE A-3. ELECTRICAL CONDUCTIVITY (MMHOS/CM) OF 30-60 CM SOIL DEPTH

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	CK	45-L†	45-H§	90-L	90-H	135-L	135-H	180-L	180-H
<u>Fall 1977</u>									
*R1	0.93	2.40	3.52	2.98	5.67	8.18	6.10	4.93	5.17
*R2	0.85	2.82	5.36	5.10	5.22	6.10	4.65	4.51	6.28
*R3	1.72	2.62	2.65	2.17	3.60	8.32	6.06	8.06	5.15
*R4	5.22	1.42	4.37	5.43	3.59	5.27	6.48	8.74	5.75
+ $\bar{x}$	2.18	2.31	3.98	3.92	4.52	6.97	5.82	6.56	5.59
<u>Spring 1977</u>									
R1	1.53	3.63	2.66	5.48	7.09	5.09	5.00	4.86	3.94
R2	2.64	3.28	3.70	6.00	3.29	5.75	7.51	8.00	7.97
R3	4.53	5.89	2.95	3.87	7.02	6.85	6.64	7.26	5.16
R4	5.62	4.03	4.27	5.13	5.17	5.48	9.62	7.38	7.91
$\bar{x}$	3.58	4.21	3.40	5.12	5.64	5.79	7.19	6.88	6.24
<u>Fall 1976</u>									
R1	1.06	4.07	2.30	5.34	4.17	4.07	6.09	5.34	5.00
R2	1.37	4.83	3.93	4.07	4.62	3.68	6.11	6.68	5.43
R3	2.68	5.19	2.08	5.65	3.16	4.76	4.98	5.79	5.62
R4	5.75	3.21	3.78	4.75	4.15	6.03	7.17	5.96	5.67
$\bar{x}$	2.71	4.33	3.02	4.95	4.02	4.64	6.09	5.94	5.43
<u>Fall 1975</u>									
R1	0.70	1.73	1.86	5.29	5.60	4.15	6.70	5.43	4.27
R2	2.58	2.04	2.78	3.77	4.86	5.07	4.71	3.99	4.11
R3	1.58	3.55	1.75	3.19	2.79	4.14	3.38	4.00	5.52
R4	7.34	2.24	2.01	4.01	3.13	5.33	4.95	6.44	6.31
$\bar{x}$	3.05	2.39	2.10	4.07	4.09	4.67	4.94	4.96	5.05
<u>Fall 1974</u>									
R1	0.51	0.64	0.54	2.18	0.77	1.36	0.77	1.11	1.29
R2	1.74	0.90	0.93	1.57	2.10	0.90	3.32	2.46	1.29
R3	1.90	1.95	0.63	1.27	1.84	1.49	0.77	2.41	1.78
R4	5.66	1.63	0.44	1.33	0.93	2.31	1.98	3.17	3.24
$\bar{x}$	2.45	1.28	0.64	1.58	1.41	1.51	1.71	2.29	1.90
<u>Fall 1973</u>									
R1	0.43	0.46	0.55	2.39	0.67	1.03	0.46	1.00	1.02
R2	1.39	1.33	1.02	2.38	1.14	1.63	0.96	4.96	1.58
R3	5.35	1.13	0.54	1.63	2.11	1.39	0.62	2.23	2.40
R4	2.69	1.57	0.88	1.78	1.07	3.09	1.77	3.02	2.36
$\bar{x}$	2.46	1.12	0.75	2.04	1.25	1.78	0.95	2.80	1.84

† L = low

§ H = high

* R1-R4 = data for replications 1 through 4

+ $\bar{x}$ = average of four replications

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TABLE A-4. ANALYSIS OF VARIANCE -- EC 30-60 CM SOIL DEPTH

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Source	DF [†]	SS ^{††}	MS [†]	F ^{††}
Row	5.00	458.53	91.71	59.85**
Column	8.00	162.17	20.27	13.23**
Interaction	40.00	105.72	2.64	1.72**
Error	162.00	248.23	1.53	
Total	215.00	974.64		

Row Contrasts	NUM DF [§]	DEN DF ^{§§}	F
1973 vs F1977	1.00	162.0	156.81**
1973 vs S1977	1.00	162.0	237.53**
1973 vs 1976	1.00	162.0	148.48**
1973 vs 1975	1.00	162.0	89.82**
1973 vs 1974	1.00	162.0	0.01NS#

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Column Contrasts	NUM DF	DEN DF	F
CK vs 45L	1.00	162.0	0.14NS
CK vs 45H	1.00	162.0	1.42NS
CK vs 90L	1.00	162.0	6.01*
CK vs 90H	1.00	162.0	4.41*
CK vs 135L	1.00	162.0	17.35**
CK vs 135H	1.00	162.0	22.92**
CK vs 180L	1.00	162.0	36.77**
CK vs 180H	1.00	162.0	20.13**
High vs Low	1.00	162.0	1.13NS

9-1/8"

† DF = degrees of freedom
 †† SS = sum of squares
 † MS = mean square
 †† F = tabular F
 § NUM = numerator
 §§ DEN = denominator
 * F.05 = 3.84 significant at the 95 percent probability level
 ** F.01 = 6.63 significant at the 99 percent probability level
 # NS = non-significant

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TABLE A-5. ELECTRICAL CONDUCTIVITY (MMHOS/CM) OF 60-90 CM SOIL DEPTH

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	CK	45-L†	45-H§	90-L	90-H	135-L	135-H	180-L	180-H
	<u>Fall 1977</u>								
*R1	1.91	4.79	6.38	5.84	6.93	8.11	4.32	3.73	6.70
*R2	4.02	7.26	4.02	5.46	8.04	7.90	5.22	6.44	7.33
*R3	4.37	5.34	5.66	5.36	7.05	7.05	5.53	8.00	7.85
*R4	8.25	4.01	5.93	5.74	5.82	7.44	8.00	8.60	9.59
+ $\bar{x}$	4.64	5.35	5.49	5.60	6.96	7.63	5.76	6.69	7.87
	<u>Spring 1977</u>								
R1	3.22	4.00	4.75	7.26	4.31	7.00	5.02	4.38	6.03
R2	5.43	6.77	5.72	5.19	5.97	5.33	5.63	6.88	5.62
R3	5.43	7.87	4.02	5.25	7.51	5.97	7.23	7.51	5.00
R4	7.40	6.42	3.15	6.00	4.58	8.14	5.67	9.33	7.46
$\bar{x}$	5.37	6.27	4.41	5.93	5.59	6.61	5.89	7.02	6.01
	<u>Fall 1976</u>								
R1	1.84	3.26	2.66	5.39	3.19	5.15	2.78	3.27	4.46
R2	4.71	4.01	4.83	4.39	3.16	5.92	3.80	4.86	3.53
R3	4.07	7.40	3.94	3.53	5.19	6.51	5.62	5.25	4.26
R4	5.08	4.52	4.02	3.35	4.13	6.32	7.69	6.42	6.76
$\bar{x}$	3.92	4.80	3.86	4.16	3.92	5.97	4.97	4.95	4.75
	<u>Fall 1975</u>								
R1	1.20	1.04	3.69	5.45	4.05	4.32	2.31	2.79	4.45
R2	5.50	4.25	1.34	5.26	5.13	5.80	4.14	4.34	4.40
R3	3.43	5.72	1.26	4.28	4.80	4.23	2.68	7.22	4.12
R4	6.97	3.26	3.19	2.52	3.20	7.85	5.79	7.01	6.34
$\bar{x}$	4.28	3.57	2.37	4.38	4.29	5.55	3.73	5.34	4.83
	<u>Fall 1974</u>								
R1	1.13	0.47	4.74	5.35	3.66	4.67	2.52	4.17	4.93
R2	4.59	3.99	4.56	5.23	6.51	5.40	5.42	5.07	4.45
R3	4.77	5.64	3.81	4.82	4.19	4.66	4.56	4.73	3.14
R4	5.55	4.50	4.79	4.17	1.97	5.09	4.29	5.85	5.79
$\bar{x}$	4.01	3.65	4.47	4.89	4.08	4.95	4.20	4.95	4.57
	<u>Fall 1973</u>								
R1	1.17	0.63	1.65	4.53	2.43	5.34	0.78	4.49	4.90
R2	4.78	3.30	4.58	4.09	4.69	4.88	2.39	6.26	5.03
R3	3.79	4.58	3.02	2.95	4.34	5.80	1.85	6.18	3.16
R4	7.11	4.94	2.82	4.20	2.29	5.72	5.05	8.31	5.91
$\bar{x}$	4.21	3.36	3.02	3.94	3.43	5.44	2.52	6.31	4.75

† L = low

§ H = high

* R1-R4 = data for replications 1 through 4

+ $\bar{x}$ = average of four replications

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TABLE A-6. ANALYSIS OF VARIANCE -- EC 60-90 CM SOIL DEPTH

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Source	DF ⁺	SS ⁺⁺	MS ⁺	F ⁺⁺
Row	5.00	147.92	29.58	13.76**
Column	8.00	97.50	12.19	5.67**
Interaction	40.00	59.44	1.49	0.69NS#
Error	162.00	348.21	2.15	
Total	215.00	653.06		

Row Contrasts	NUM DF [§]	DEN DF ^{§§}	F
1973 vs F1977	1.00	162.0	56.05**
1973 vs S1977	1.00	162.0	40.36**
1973 vs 1976	1.00	162.0	2.90NS
1973 vs 1975	1.00	162.0	0.28NS
1973 vs 1974	1.00	162.0	1.22NS

Column Contrasts	NUM DF	DEN DF	F
CK vs 45L	1.00	162.0	0.05NS
CK vs 45H	1.00	162.0	1.21NS
CK vs 90L	1.00	162.0	0.95NS
CK vs 90H	1.00	162.0	0.53NS
CK vs 135L	1.00	162.0	14.66**
CK vs 135H	1.00	162.0	0.06NS
CK vs 180L	1.00	162.0	12.12**
CK vs 180H	1.00	162.0	6.29*
High vs Low	1.00	162.0	9.37**

+ DF = degrees of freedom

++ SS = sum of squares

+ MS = mean square

++ F = tabular F

§ NUM = numerator

§§ DEN = denominator

* F.05 = 3.84 significant at the 95 percent probability level

** F.01 = 6.63 significant at the 99 percent probability level

NS = non-significant

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TABLE A-7. ELECTRICAL CONDUCTIVITY (MMHOS/CM) OF 90-150 CM SOIL DEPTH

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	CK	45-L†	45-H [§]	90-L	90-H	135-L	135-H	180-L	180-H
					Fall 1977				
*R1	7.72	7.00	6.49	9.19	9.55	4.02	3.07	5.17	3.05
*R2	4.86	5.64	8.73	8.37	5.64	5.64	6.15	7.12	7.61
*R3	6.18	7.85	4.22	4.70	3.67	5.67	8.37	9.16	4.47
*R4	7.05	4.51	3.38	5.49	3.67	5.53	4.37	6.84	6.42
+ $\bar{x}$	6.45	6.25	5.70	6.94	5.63	5.21	5.49	7.07	5.39
					Fall 1974				
R1	5.88	5.32	4.81	7.33	5.83	6.24	4.69	6.33	7.09
R2	5.37	4.84	7.90	6.76	6.76	5.71	7.36	6.22	4.97
R3	5.30	6.55	4.77	4.25	4.63	5.62	5.85	6.10	4.41
R4	5.47	6.00	6.19	6.27	4.22	5.85	5.00	6.59	6.67
$\bar{x}$	5.51	5.68	5.92	6.15	5.36	5.85	5.72	6.31	5.78
					Fall 1973				
R1	4.39	4.71	4.83	5.74	6.12	6.22	3.61	6.57	8.33
R2	9.35	5.95	8.40	5.63	15.56	3.15	5.44	3.37	6.05
R3	5.15	7.06	2.08	5.01	5.27	6.98	5.12	5.84	4.14
R4	6.68	6.65	4.87	5.48	4.37	6.47	6.10	7.57	5.78
$\bar{x}$	6.39	6.09	5.05	5.46	7.83	5.70	5.07	5.84	6.08

† L = low

§ H = high

* R1-R4 = data for replications 1 through 4

+ $\bar{x}$ = average of four replications

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TABLE A-8. ANALYSIS OF VARIANCE -- EC 90-150 CM SOIL DEPTH

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Source	DF ⁺	SS ⁺⁺	MS [†]	F ^{††}
Row	2.00	0.80	0.40	0.11NS [#]
Column	8.00	11.89	1.49	0.43NS
Interaction	16.00	28.63	1.79	0.51NS
Error	81.00	281.48	3.48	
Total	107.00	322.81		
<u>Row Contrasts</u>		<u>NUM DF[§]</u>	<u>DEN DF^{§§}</u>	<u>F</u>
1973 vs 1977		1.00	162.0	0.08NS
1973 vs 1974		1.00	162.0	0.29NS
<u>Column Contrasts</u>		<u>NUM DF</u>	<u>DEN DF</u>	<u>F</u>
CK vs 45L	6-1/2"	1.00	162.0	0.02NS
CK vs 45H		1.00	162.0	0.54NS
CK vs 90L		1.00	162.0	0.01NS
CK vs 90H		1.00	162.0	0.04NS
CK vs 135L	9-1/8"	1.00	162.0	0.48NS
CK vs 135H		1.00	162.0	0.82NS
CK vs 180L		1.00	162.0	0.14NS
CK vs 180H		1.00	162.0	0.23NS
High vs Low		1.00	162.0	0.60NS

+ DF = degrees of freedom
 ++ SS = sum of squares
 † MS = mean square
 †† F = tabular F
 § NUM = numerator
 §§ DEN = denominator
 # NS = non-significant

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TABLE A-9. SODIUM CONTENT (MEQ/100G) 0-30 CM SOIL DEPTH

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	CK	45-L†	45-H§	90-L	90-H	135-L	135-H	180-L	180-H
<u>Fall 1977</u>									
*R1	0.13	0.23	0.32	0.25	0.48	0.49	0.61	0.29	0.52
*R2	0.21	0.15	0.27	0.26	0.28	0.45	0.75	0.19	0.56
*R3	0.25	0.22	0.36	0.27	0.41	0.36	0.52	0.33	0.48
*R4	0.14	0.18	0.32	0.12	0.41	0.30	0.52	0.39	0.68
+ $\bar{x}$	0.18	0.20	0.32	0.23	0.40	0.40	0.60	0.30	0.56
<u>Spring 1977</u>									
R1	0.17	0.20	0.40	0.21	0.61	0.45	0.60	0.17	0.65
R2	0.14	0.16	0.29	0.24	0.33	0.31	0.54	0.24	0.02
R3	0.12	0.26	0.20	0.24	0.32	0.28	0.57	0.31	0.60
R4	0.14	0.20	0.32	0.34	0.42	0.42	0.52	0.23	0.62
$\bar{x}$	0.14	0.21	0.30	0.26	0.42	0.37	0.56	0.24	0.47
<u>Fall 1976</u>									
R1	0.10	0.07	0.56	0.18	0.75	0.41	0.59	0.33	2.44
R2	0.16	0.18	0.35	0.17	0.51	0.38	0.79	0.43	0.68
R3	0.13	0.28	0.29	0.21	0.62	0.56	0.83	0.17	1.01
R4	0.26	0.10	0.27	0.50	0.58	0.45	0.22	0.44	1.47
$\bar{x}$	0.16	0.16	0.37	0.27	0.62	0.45	0.61	0.34	1.40
<u>Fall 1975</u>									
R1	0.06	0.14	0.65	0.27	0.66	1.28	1.04	0.40	0.42
R2	0.09	0.35	0.44	0.26	0.45	0.33	0.67	1.32	0.67
R3	0.11	0.24	0.22	0.28	0.70	0.44	0.97	0.36	0.92
R4	0.25	0.16	0.41	0.38	0.48	0.68	0.85	0.52	1.16
$\bar{x}$	0.13	0.22	0.43	0.30	0.57	0.68	0.88	0.65	0.79
<u>Fall 1974</u>									
R1	0.07	0.09	0.16	0.26	0.49	0.37	0.59	0.31	0.58
R2	0.07	0.21	0.18	0.24	0.23	0.21	0.52	0.43	0.48
R3	0.06	0.14	0.14	0.22	0.36	0.36	0.57	0.36	0.74
R4	0.27	0.15	0.25	0.37	0.35	0.59	0.48	0.23	0.46
$\bar{x}$	0.12	0.15	0.18	0.27	0.36	0.38	0.54	0.33	0.57
<u>Fall 1973</u>									
R1	0.06	0.13	0.09	0.07	0.06	0.17	0.05	0.05	0.05
R2	0.05	0.77	0.07	0.05	0.04	0.06	0.06	0.09	0.04
R3	0.02	0.05	0.10	0.03	0.04	0.04	0.05	0.10	0.06
R4	0.08	0.04	0.05	0.07	0.02	0.11	0.07	0.09	0.08
$\bar{x}$	0.05	0.25	0.08	0.06	0.04	0.10	0.06	0.08	0.06

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† L = low
§ H = high
* R1-R4 = data for replications 1 through 4
+ $\bar{x}$ = average of four replications

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TABLE A-10. ANALYSIS OF VARIANCE -- NA 0-30 CM SOIL DEPTH

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Source	DF [†]	SS ^{††}	MS [†]	F ^{††}
Row	5.00	4.24	0.85	26.56**
Column	8.00	5.23	0.65	20.47**
Interaction	40.00	3.90	0.10	3.05**
Error	162.00	5.17	0.03	
Total	215.00	18.55		

Row Contrasts	NUM DF [§]	DEN DF ^{§§}	F
1973 vs 1977	1.00	162.0	60.62**
1973 vs SP1977	1.00	162.0	50.28**
1973 vs 1976	1.00	162.0	135.45**
1973 vs 1975	1.00	162.0	158.13**
1973 vs 1974	1.00	162.0	47.46**

6-1/2"

Column Contrasts	NUM DF	DEN DF	F
High vs Low	1.00	162.0	48.30**
CK vs 45L	1.00	162.0	1.59NS#
CK vs 45H	1.00	162.0	8.31**
CK vs 90L	1.00	162.0	3.60NS
CK vs 90H	1.00	162.0	27.22**
CK vs 135L	1.00	162.0	26.38**
CK vs 135H	1.00	162.0	63.16**
CK vs 180L	1.00	162.0	14.04**
CK vs 180H	1.00	162.0	97.88**

9-1/8"

+ DF = degrees of freedom
 †† SS = sum of squares
 † MS = mean square
 †† F = tabular F
 § NUM = numerator
 §§ DEN = denominator
 ** F.01 = 6.63 significant at the 99 percent probability level
 # NS = non-significant

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TABLE A-11. SODIUM CONTENT (MEQ/100G) 30-60 CM SOIL DEPTH

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	CK	45-L†	45-H§	90-L	90-H	135-L	135-H	180-L	180-H
<u>Fall 1977</u>									
*R1	0.27	0.22	0.20	0.24	0.48	0.47	0.33	0.29	0.57
*R2	0.34	0.28	0.27	0.43	0.36	0.55	0.46	0.60	0.61
*R3	0.24	0.39	0.23	0.26	0.41	0.43	0.68	0.32	0.66
*R4	0.36	0.25	0.28	0.28	0.33	0.30	0.16	0.49	0.49
+ $\bar{x}$	0.30	0.29	0.25	0.30	0.40	0.44	0.41	0.43	0.58
<u>Spring 1977</u>									
R1	0.18	0.12	0.20	0.25	0.38	0.36	0.30	0.30	0.48
R2	0.24	0.37	0.22	0.31	0.30	0.29	0.32	0.29	0.36
R3	0.32	0.11	0.14	0.21	0.17	0.42	0.59	0.40	0.33
R4	0.36	0.24	0.16	0.29	0.23	0.45	0.58	0.55	0.09
$\bar{x}$	0.28	0.21	0.18	0.27	0.27	0.38	0.45	0.39	0.32
<u>Fall 1976</u>									
R1	0.17	0.12	0.17	0.27	0.31	0.28	0.49	0.32	0.53
R2	0.26	0.18	0.13	0.21	0.35	0.37	0.56	0.30	0.41
R3	0.23	0.41	0.15	0.23	0.31	0.41	0.52	0.40	0.28
R4	0.53	0.18	0.22	0.24	0.24	0.25	0.39	0.33	0.43
$\bar{x}$	0.30	0.22	0.17	0.24	0.30	0.33	0.49	0.34	0.41
<u>Fall 1975</u>									
R1	0.08	0.07	0.64	0.11	0.29	0.22	0.12	0.19	0.57
R2	0.37	0.24	0.13	0.23	0.17	0.30	0.29	0.23	0.69
R3	0.08	0.28	0.09	0.12	0.22	0.46	0.30	0.21	0.08
R4	0.14	0.08	0.11	0.09	0.06	0.25	0.11	0.30	0.38
$\bar{x}$	0.17	0.17	0.24	0.14	0.19	0.31	0.21	0.23	0.43
<u>Fall 1974</u>									
R1	0.16	1.02	0.14	0.38	0.23	0.31	0.11	0.24	0.31
R2	0.27	0.22	0.23	0.29	0.26	0.22	0.21	0.33	0.27
R3	0.22	0.30	0.17	0.21	0.23	0.22	0.25	0.45	0.20
R4	0.64	0.23	0.25	0.22	0.17	0.25	0.18	0.34	0.28
$\bar{x}$	0.32	0.44	0.20	0.28	0.22	0.25	0.19	0.34	0.27
<u>Fall 1973</u>									
R1	0.09	0.10	0.03	0.22	0.14	1.31	0.14	0.11	0.25
R2	0.26	0.18	0.47	0.22	0.16	0.36	0.58	0.41	0.16
R3	0.02	0.24	0.13	0.08	0.27	0.27	0.14	0.26	0.22
R4	0.41	0.12	0.12	0.16	0.09	0.27	0.12	0.55	0.27
$\bar{x}$	0.20	0.16	0.19	0.17	0.17	0.55	0.25	0.33	0.23

† L = low

§ H = high

* R1-R4 = data for replications 1 through 4

+ $\bar{x}$ = average of four replications

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TABLE A-12. ANALYSIS OF VARIANCE -- NA 30-60 CM SOIL DEPTH

Source	DF ⁺	SS ⁺⁺	MS ⁺	F ⁺⁺
Row	5.00	0.48	0.10	4.57**
Column	8.00	0.80	0.10	4.71**
Interaction	40.00	1.08	0.03	1.28NS#
Error	162.00	3.42	0.02	
Total	215.00	5.78		

Row Contrasts	NUM DF [§]	DEN DF ^{§§}	F
1973 vs F1977	1.00	162.0	20.88**
1973 vs S1977	1.00	162.0	3.87*
1973 vs 1976	1.00	162.0	5.01*
1973 vs 1975	1.00	162.0	0.39NS
1973 vs 1974	1.00	162.0	1.15NS
High vs Low	1.00	162.0	0.17NS

Column Contrasts	NUM DF	DEN DF	F
High vs Low	1.00	162.0	0.17NS
CK vs 45L	1.00	162.0	0.08NS
CK vs 45H	1.00	162.0	1.83NS
CK vs 90L	1.00	162.0	0.47NS
CK vs 90H	1.00	162.0	0.01NS
CK vs 135L	1.00	162.0	7.63**
CK vs 135H	1.00	162.0	2.82NS
CK vs 180L	1.00	162.0	3.83NS
CK vs 180H	1.00	162.0	7.11**

+ DF = degrees of freedom
 ++ SS = sum of squares
 + MS = mean square
 ++ F = tabular F
 § NUM = numerator
 §§ DEN = denominator
 * F.05 = 3.84 significant at the 95 percent probability level
 ** F.01 = 6.63 significant at the 99 percent probability level
 # NS = non-significant

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TABLE A-13. SODIUM CONTENT (MEQ/100G) 60-90 CM SOIL DEPTH

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	CK	45-L†	45-H ^s	90-L	90-H	135-L	135-H	180-L	180-H
					<u>Fall 1977</u>				
*R1	0.44	0.16	0.48	0.59	0.32	0.25	0.62	0.36	0.24
*R2	0.29	0.24	0.25	0.44	0.47	0.35	0.37	0.33	0.67
*R3	0.44	0.58	0.16	0.42	0.36	0.49	0.32	0.28	0.29
*R4	1.20	0.34	0.42	0.17	0.34	0.03	0.24	0.66	0.07
+ $\bar{x}$	0.59	0.33	0.33	0.41	0.37	0.28	0.39	0.41	0.32
					<u>Spring 1977</u>				
R1	0.47	0.43	0.45	0.68	0.32	0.28	0.16	0.20	0.33
R2	0.44	0.24	0.25	0.27	0.41	0.45	0.33	0.27	0.28
R3	0.45	0.91	0.18	0.12	0.10	0.45	0.37	0.47	0.25
R4	0.38	0.25	0.26	0.24	0.23	0.38	0.15	0.66	0.49
$\bar{x}$	0.44	0.46	0.29	0.33	0.27	0.39	0.25	0.40	0.34
					<u>Fall 1976</u>				
R1	0.38	0.30	0.54	0.55	0.26	0.26	0.20	0.26	0.70
R2	0.55	0.37	0.28	0.46	0.11	0.35	0.23	0.53	0.36
R3	0.18	0.53	0.21	0.20	0.14	0.39	0.35	0.52	0.23
R4	0.50	0.31	0.47	0.15	0.29	0.10	0.74	0.40	0.17
$\bar{x}$	0.40	0.38	0.38	0.34	0.20	0.28	0.38	0.43	0.37
					<u>Fall 1975</u>				
R1	0.25	0.19	0.31	0.15	0.34	0.22	0.12	0.29	0.29
R2	0.46	0.34	0.21	0.21	1.51	0.29	0.22	0.26	0.33
R3	0.22	0.37	0.17	0.26	0.15	0.40	0.41	0.17	0.10
R4	0.49	0.16	0.20	0.21	0.13	0.27	0.17	0.25	0.50
$\bar{x}$	0.36	0.27	0.22	0.16	0.53	0.32	0.23	0.24	0.31
					<u>Fall 1974</u>				
R1	0.53	0.62	0.55	0.62	0.62	0.52	0.34	0.36	0.59
R2	0.47	0.33	0.48	0.70	0.45	0.53	0.64	0.49	0.35
R3	0.39	0.62	0.34	0.28	0.36	0.30	0.45	0.48	0.34
R4	0.42	0.49	0.55	0.43	0.32	0.40	0.24	0.38	0.44
$\bar{x}$	0.45	0.52	0.48	0.51	0.44	0.44	0.42	0.43	0.43
					<u>Fall 1973</u>				
R1	0.38	1.29	0.93	0.35	1.75	0.39	0.21	0.28	0.68
R2	0.41	0.32	0.58	0.41	0.39	0.43	0.20	0.57	0.49
R3	0.53	0.56	0.25	0.24	0.10	0.46	0.35	0.33	0.25
R4	0.38	0.33	0.28	0.29	0.23	0.44	0.24	0.47	0.29
$\bar{x}$	0.43	0.63	0.51	0.32	0.62	0.43	0.25	0.41	0.43

† L = low

^s H = high

* R1-R4 = data for replications 1 through 4

+ $\bar{x}$ = average of four replications

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TABLE A-14. ANALYSIS OF VARIANCE -- NA 60-90 CM SOIL DEPTH

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Source	DF ⁺	SS ⁺⁺	MS ⁺	F ⁺⁺
Row	5.00	0.71	0.14	2.98*
Column	8.00	0.31	0.04	0.82NS#
Interaction	40.00	1.19	0.03	0.62NS
Error	162.00	7.76	0.05	
Total	215.00	9.97		
<u>Row Contrasts</u>		<u>NUM DF^s</u>	<u>DEN DF^{ss}</u>	<u>F</u>
1973 vs F1977		1.00	162.0	2.51
1973 vs SP1977		1.00	162.0	5.27
1973 vs 1976		1.00	162.0	5.36
1973 vs 1975		1.00	162.0	13.50
1973 vs 1974		1.00	162.0	0.05
<u>Columns Contrasts</u>		<u>NUM DF</u>	<u>DEN DF</u>	<u>F</u>
High vs Low		1.00	162.0	0.22
CK vs 45L	9-1/8"	1.00	162.0	0.06
CK vs 45H		1.00	162.0	1.49
CK vs 90L		1.00	162.0	2.55
CK vs 90H		1.00	162.0	0.39
CK vs 135L		1.00	162.0	1.96
CK vs 135H		1.00	162.0	3.86
CK vs 180L		1.00	162.0	0.83
CK vs 180H		1.00	162.0	1.60

+ DF = degree of freedom
 ++ SS = sum of squares
 + MS = mean square
 ++ F = tabular F
 s NUM = numerator
 ss DEN = denominator
 * F.05 = 3.84 significant at the 95 percent probability level
 # NS = non-significant

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TABLE A-15. SODIUM CONTENT (MEQ/100G) 90-150 CM SOIL DEPTH

	CK	45-L [†]	45-H [§]	90-L	90-H	135-L	135-H	180-L	180-H
<u>Fall 1977</u>									
*R1	0.61	0.49	0.58	0.28	0.26	0.73	0.23	0.20	0.20
*R2	0.37	0.18	0.69	0.55	0.77	0.40	0.28	0.72	0.52
*R3	0.56	0.88	0.60	0.56	0.31	0.42	0.88	0.24	0.30
*R4	0.55	0.48	0.38	0.55	0.26	0.49	0.26	0.70	0.76
+ $\bar{x}$	0.52	0.51	0.56	0.49	0.40	0.51	0.41	0.47	0.45
<u>Fall 1974</u>									
R1	0.85	0.85	0.69	0.76	0.80	0.74	0.78	0.60	0.62
R2	0.36	0.73	0.47	0.70	0.53	0.60	0.70	1.68	0.45
R3	0.42	0.60	0.43	0.15	0.38	0.42	0.81	0.60	0.40
R4	0.38	0.57	0.71	0.45	0.44	0.46	0.33	0.18	0.34
$\bar{x}$	0.50	0.69	0.58	0.52	0.54	0.56	0.66	0.77	0.45
<u>Fall 1973</u>									
R1	0.55	0.39	0.43	0.50	0.28	0.43	0.51	0.51	0.57
R2	0.38	0.50	0.50	0.43	0.40	0.36	0.46	1.22	0.48
R3	0.25	0.60	0.18	0.30	0.18	0.43	0.50	0.43	0.33
R4	0.34	0.36	0.40	0.40	0.26	0.61	0.31	0.39	0.30
$\bar{x}$	0.38	0.46	0.38	0.41	0.28	0.46	0.45	0.64	0.42

† L = low

§ H = high

* R1-R4 = data for replications 1 through 4

+ $\bar{x}$ = average of four replications

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TABLE A-16. ANALYSIS OF VARIANCE -- NA 90-150 CM SOIL DEPTH

Source	DF ⁺	SS ⁺⁺	MS [†]	F ^{††}
Row	5.00	13.79	2.76	105.98**
Column	8.00	0.19	0.02	0.93NS#
Interaction	40.00	0.51	0.01	0.49NS
Error	162.00	4.21	0.03	
Total	215.00	18.71		
<u>Row Contrasts</u>		<u>NUM DF[§]</u>	<u>DEN DF^{§§}</u>	<u>F</u>
1973 vs 1977		1.00	162.0	2.51NS
1973 vs 1974		1.00	162.0	24.31**
<u>Column Contrasts</u>		<u>NUM DF</u>	<u>DEN DF</u>	<u>F</u>
High vs Low	6-1/2"	1.00	162.0	2.55NS
CK vs 45L		1.00	162.0	0.82NS
CK vs 45H		1.00	162.0	0.16NS
CK vs 90L		1.00	162.0	0.00NS
CK vs 90H	9-1/8"	1.00	162.0	0.45NS
CK vs 135L		1.00	162.0	0.18NS
CK vs 135H		1.00	162.0	0.15NS
CK vs 180L		1.00	162.0	2.74NS
CK vs 180H		1.00	162.0	0.10NS

+ DF = degree of freedom
 ++ SS = sum of squares
 † MS = mean square
 †† F = tabular F
 § NUM = numerator
 §§ DEN = denominator
 ** F.01 = 6.63 significant at the 99 percent probability level
 # NS = non-significant

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TABLE A-17. SODIUM ADSORPTION RATIO FOR 0-30 CM SOIL DEPTH

	CK	45-L†	45-H‡	90-L	90-H	135-L	135-H	180-L	180-H
<u>Fall 1977</u>									
*R1	0.15	0.33	0.51	0.78	1.60	1.55	2.14	1.01	2.09
*R2	0.23	0.50	0.75	0.58	1.03	1.46	0.14	1.20	2.05
*R3	0.24	0.74	0.87	0.57	0.83	1.25	2.24	0.99	1.74
*R4	0.39	0.49	0.80	0.43	1.15	0.96	1.87	1.02	1.72
+ $\bar{x}$	0.25	0.52	0.73	0.59	1.15	1.31	1.60	1.06	1.90
<u>Spring 1977</u>									
R1	0.28	0.51	1.29	0.61	1.96	1.30	2.74	1.30	4.24
R2	0.30	0.59	0.80	0.68	0.86	2.01	2.41	2.78	3.29
R3	0.61	0.74	0.62	1.02	1.88	2.42	2.29	1.22	3.39
R4	0.79	0.93	0.84	0.98	1.67	1.40	3.14	1.66	3.05
$\bar{x}$	0.50	0.69	0.89	0.82	1.59	1.78	2.65	1.74	3.49
<u>Fall 1976</u>									
R1	0.04	1.00	1.39	1.05	2.64	2.11	3.93	1.72	3.57
R2	0.28	0.72	1.38	1.13	1.39	1.76	3.19	2.07	3.50
R3	0.25	0.68	0.92	1.80	2.24	1.86	2.97	1.34	3.67
R4	0.54	0.71	0.99	0.76	1.78	2.40	0.77	0.60	3.38
$\bar{x}$	0.28	0.78	1.17	1.19	2.01	2.03	2.72	1.43	3.53
<u>Fall 1975</u>									
R1	0.07	0.44	0.06	0.65	3.62	0.43	3.41	1.95	5.01
R2	0.53	0.43	2.12	1.23	2.09	2.94	4.89	2.88	5.49
R3	0.39	0.82	0.89	0.94	3.25	2.23	3.61	1.81	3.73
R4	0.54	0.45	1.30	1.24	2.07	2.88	3.44	2.54	4.07
$\bar{x}$	0.38	0.54	1.09	1.02	2.76	2.12	3.84	2.30	4.58
<u>Fall 1974</u>									
R1	0.38	0.47	0.89	1.01	1.81	1.60	2.66	1.40	2.22
R2	0.36	0.79	0.82	0.92	1.04	0.93	1.73	1.74	1.98
R3	0.32	0.42	0.45	0.67	1.32	1.44	2.01	1.17	2.90
R4	0.88	0.48	0.97	1.72	1.20	2.46	1.80	1.47	1.87
$\bar{x}$	0.49	0.54	0.78	1.08	1.34	1.61	2.05	1.45	2.24
<u>Fall 1973</u>									
R1	0.20	0.22	0.34	0.27	0.26	0.26	0.23	0.24	0.33
R2	0.28	0.24	0.24	0.32	0.29	0.27	0.74	0.34	0.26
R3	0.49	0.38	1.06	0.42	0.47	0.49	0.32	0.65	0.32
R4	0.64	0.44	0.33	0.48	0.42	0.40	0.30	0.65	0.63
$\bar{x}$	0.40	0.32	0.49	0.37	0.36	0.36	0.40	0.47	0.39

† L = low

‡ H = high

* R1-R4 = data for replications 1 through 4

+ $\bar{x}$ = average of four replications

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TABLE A-18. SODIUM ADSORPTION RATIO FOR 30-60 CM SOIL DEPTH

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	CK	45-L†	45-H [§]	90-L	90-H	135-L	135-H	180-L	180-H
<u>Fall 1977</u>									
*R1	0.31	0.47	0.85	0.87	1.89	1.43	1.87	1.28	2.77
*R2	0.52	0.61	0.84	0.94	1.57	1.28	2.78	1.32	3.05
*R3	0.34	1.06	0.55	0.88	1.91	1.73	2.12	1.34	3.01
*R4	1.63	0.55	0.99	0.85	1.59	1.48	2.16	1.87	2.21
+ $\bar{x}$	0.70	0.67	0.81	0.89	1.74	1.48	2.23	1.45	2.76
<u>Spring 1977</u>									
R1	0.49	0.81	0.89	0.78	1.51	1.61	2.60	1.53	2.38
R2	0.78	0.53	0.79	0.89	1.26	1.91	2.19	1.96	2.49
R3	0.56	1.59	0.65	1.22	2.24	1.67	2.85	1.16	3.12
R4	2.40	0.32	0.67	0.75	2.25	2.10	2.85	1.38	3.66
$\bar{x}$	1.06	0.81	0.75	0.91	1.82	1.82	2.62	1.51	2.91
<u>Fall 1976</u>									
R1	0.28	0.42	0.87	0.85	0.99	1.38	1.81	0.96	2.28
R2	0.94	0.97	0.72	0.74	1.14	0.98	1.37	1.58	2.24
R3	0.69	0.81	0.49	0.81	0.93	1.32	2.12	1.09	2.19
R4	1.73	0.48	0.75	1.26	1.14	1.64	1.94	1.60	2.24
$\bar{x}$	0.91	0.67	0.71	0.92	1.05	1.33	1.81	1.31	2.24
<u>Fall 1975</u>									
R1	0.37	0.27	0.06	1.03	1.19	0.92	1.56	0.77	1.84
R2	1.07	0.47	0.41	0.91	1.06	1.13	1.00	1.03	2.21
R3	0.49	0.80	0.45	0.64	0.73	0.85	0.99	0.90	1.39
R4	1.98	0.40	0.56	0.70	0.67	1.24	1.16	1.41	1.88
$\bar{x}$	0.98	0.49	0.37	0.82	0.91	1.04	1.18	1.03	1.83
<u>Fall 1974</u>									
R1	0.61	5.80	0.71	1.02	0.63	1.02	0.58	0.72	1.09
R2	0.97	0.91	0.83	0.83	1.12	0.86	0.73	0.97	0.92
R3	0.82	0.87	0.55	0.55	0.67	0.63	0.86	1.25	0.68
R4	2.09	0.72	0.85	0.60	0.42	0.90	0.47	1.53	1.04
$\bar{x}$	1.12	2.08	0.74	0.75	0.71	0.85	0.66	1.12	0.93
<u>Fall 1973</u>									
R1	0.42	0.38	2.26	0.71	0.42	0.57	0.36	0.49	0.66
R2	0.75	0.64	0.58	0.71	0.55	0.94	0.56	1.65	0.62
R3	1.47	0.94	0.58	0.73	0.07	0.88	0.72	0.94	1.00
R4	1.40	0.93	0.55	0.93	0.75	1.09	0.96	1.66	1.14
$\bar{x}$	1.01	0.72	0.99	0.77	0.45	0.87	0.65	1.19	0.86

† L = low

§ H = high

* R1-R4 = data for replications 1 through 4

+ $\bar{x}$ = average of four replications

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TABLE A-19. SODIUM ADSORPTION RATIO FOR 60-90 CM SOIL DEPTH

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CK	45-L†	45-H [§]	90-L	90-H	135-L	135-H	180-L	180-H
<u>Fall 1977</u>								
*R1	1.27	0.94	2.47	1.79	1.84	1.51	2.27	0.73
*R2	1.73	2.13	1.46	2.15	2.21	2.15	1.01	1.69
*R3	1.14	1.57	1.18	1.04	0.98	1.58	1.62	1.96
*R4	2.20	1.34	1.39	1.45	1.08	1.57	1.01	2.08
+ $\bar{x}$	1.59	1.50	1.63	1.61	1.53	1.70	1.48	1.62
<u>Spring 1977</u>								
R1	1.02	0.61	1.47	1.88	1.18	1.39	0.72	1.36
R2	1.52	1.39	1.55	1.96	3.17	2.16	1.96	1.83
R3	1.52	2.28	0.43	1.17	1.33	1.26	1.24	3.06
R4	3.03	1.32	0.90	1.82	1.30	2.77	0.95	3.38
$\bar{x}$	1.77	1.40	1.09	1.71	1.75	1.90	1.22	2.41
<u>Fall 1976</u>								
R1	0.85	1.23	2.21	1.71	1.38	1.49	0.62	0.92
R2	1.48	1.42	1.80	2.05	3.44	2.03	1.51	2.89
R3	1.52	2.65	0.79	1.38	1.06	1.10	1.18	2.19
R4	2.61	1.36	0.85	1.59	0.97	2.70	3.68	2.46
$\bar{x}$	1.62	1.67	1.41	1.68	1.71	1.83	1.75	2.12
<u>Fall 1975</u>								
R1	0.92	0.92	1.84	1.63	1.62	1.70	0.77	1.18
R2	1.64	0.92	0.70	1.25	1.92	1.91	1.23	1.63
R3	1.01	1.60	0.72	1.22	0.95	1.03	1.32	2.18
R4	2.02	1.39	0.96	0.91	1.32	1.47	0.86	1.93
$\bar{x}$	1.40	1.21	1.06	1.25	1.45	1.53	1.05	1.73
<u>Fall 1974</u>								
R1	1.65	1.70	1.82	1.98	1.60	1.63	1.41	1.36
R2	1.53	1.00	1.93	1.75	2.88	1.78	1.99	1.69
R3	1.39	1.51	1.17	1.08	1.01	1.00	1.34	1.68
R4	1.93	1.59	1.27	1.60	1.02	1.84	0.85	1.99
$\bar{x}$	1.63	1.45	1.55	1.60	1.63	1.56	1.40	1.68
<u>Fall 1973</u>								
R1	1.37	0.92	1.93	1.26	1.41	1.05	0.79	0.97
R2	1.47	1.08	2.02	1.27	1.61	1.32	1.24	1.80
R3	1.04	1.65	1.10	1.18	1.09	1.80	1.36	2.70
R4	2.41	1.63	1.15	1.31	1.05	2.03	1.28	2.89
$\bar{x}$	1.57	1.32	1.55	1.26	1.29	1.55	1.17	2.09

† L = low
§ H = high

* R1-R4 = data for replications 1 through 4

+ $\bar{x}$ = average of four replications

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TABLE A-20. SODIUM ADSORPTION RATIO FOR 60-150 CM SOIL DEPTH

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	CK	45-L†	45-H ^s	90-L	90-H	135-L	135-H	180-L	180-H
Fall 1973									
*R1	2.90	2.64	3.35	3.51	3.69	2.45	1.14	1.83	3.90
*R2	2.13	1.85	3.29	4.21	1.85	1.80	2.00	2.42	3.73
*R3	1.94	3.05	1.63	1.56	1.43	2.06	2.77	3.48	1.95
*R4	2.08	1.83	1.16	1.70	1.64	1.65	1.70	2.37	2.07
+ $\bar{x}$	2.26	2.34	2.36	2.75	2.15	1.99	1.90	2.53	2.91
Fall 1974									
R1	2.05	2.11	2.97	3.38	2.94	2.84	2.24	2.71	3.35
R2	1.75	1.86	3.77	2.93	3.06	1.94	3.37	0.25	1.74
R3	1.55	1.82	1.51	1.35	1.37	1.39	1.78	1.97	1.45
R4	1.87	1.85	1.83	2.27	1.36	2.01	1.23	2.22	2.38
$\bar{x}$	1.81	1.91	2.52	2.48	2.18	2.05	2.16	1.79	2.23
Fall 1973									
R1	2.23	1.28	2.94	1.92	2.89	1.73	2.08	2.21	3.09
R2	2.06	1.63	3.47	1.88	2.52	1.60	1.85	1.37	1.90
R3	1.78	2.53	0.98	1.54	1.52	2.90	1.49	2.73	1.73
R4	2.60	2.47	1.67	1.62	1.69	2.47	1.74	2.89	2.31
$\bar{x}$	2.17	1.98	2.27	1.74	2.13	2.18	1.79	2.30	2.26

† L = low

^s H = high

* R1-R4 = data for replications 1 through 4

+ $\bar{x}$ = average of four replications

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APPENDIX B

WATER INFILTRATION AND CHEMICAL ANALYSES

Water stability ratio data were compared by analysis of variance and the results given.

Chemical analyses for all runoff waters collected from manure treatment plots are shown.

Analysis of variance results for WSR

(Table B-1)

Analysis of runoff waters 1977

(Table B-2)

Analysis of runoff waters 1978

(Table B-3)

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TABLE B-1. ANALYSIS OF VARIANCE RESULTS FOR WSR

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Variation	-----1975-----			-----1976-----		
	DF§	MS+	F†	DF	MS	F
Waste rates	3	0.1539	5.33*	3	0.0137	5.62
Salt levels	1	0.0638	2.21	1	0.0025	1.03
Interaction	3	0.0199	0.69	3	0.0049	2.01
Error	8	0.0289		8	0.0024	
Total	15			15		
Sub-total	7			7		

1975 Dunnet's significant difference, $d (.01) = 0.45$, $d (.05) = 0.32$

1976 Dunnet's significant difference, $d (.01) = 0.13$, $d (.05) = 0.09$

§ DF = degrees of freedom

+ MS = mean square

† F = computed F value

* = significant at the 95 percent probability level

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TABLE B-2. ANALYSIS OF RUNOFF WATERS ON JUNE 22, 1977

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	90-L [†]	90-H [‡]	180-L	180-H
Calcium (ppm)				
*R1	7.40	10.30	3.50	7.00
*R2	6.50	4.90	0.00	4.25
*R3	8.30	3.90	0.00	0.00
*R4	0.00	4.30	0.00	0.00
+ $\bar{x}$	7.40	5.85	3.50	5.63
Magnesium (ppm)				
R1	1.80	2.50	3.50	1.50
R2	2.50	1.10	0.00	2.50
R3	3.10	3.80	0.00	0.00
R4	0.00	2.75	0.00	0.00
$\bar{x}$	2.50	2.54	3.50	2.00
Sodium (ppm)				
R1	1.60	1.60	1.10	1.40
R2	1.10	1.10	0.00	1.60
R3	0.85	3.80	0.00	0.00
R4	0.00	1.45	0.00	0.00
$\bar{x}$	1.20	1.99	1.10	1.50
Potassium (ppm)				
R1	5.30	7.00	18.10	7.90
R2	10.20	5.70	0.00	9.55
R3	7.74	8.20	0.00	0.00
R4	0.00	8.05	0.00	0.00
$\bar{x}$	7.75	7.24	18.10	8.73
Nitrate Nitrogen (ppm)				
R1	0.59	0.21	0.94	0.60
R2	0.71	0.48	0.00	0.41
R3	0.67	0.72	0.00	0.00
R4	0.00	0.63	0.00	0.00
$\bar{x}$	0.66	0.51	0.94	0.80
Chloride (ppm)				
R1	1.20	7.40	2.00	2.10
R2	0.65	0.83	0.00	1.25
R3	0.88	1.60	0.00	0.00
R4	0.00	0.78	0.00	0.00
$\bar{x}$	0.95	2.65	2.00	1.68

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TABLE B-2 (continued)

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	90-L	90-H	180-L	180-H
pH				
R1	7.50	6.91	6.58	7.55
R2	7.14	7.61	0.00	6.42
R3	6.90	7.72	0.00	0.00
R4	0.00	7.26	0.00	0.00
$\bar{x}$	7.18	7.38	6.58	6.99
Electrical Conductivity (μ mhos/cm)				
R1	64.00	76.00	82.50	71.00
R2	63.50	41.30	0.00	52.75
R3	76.80	115.00	0.00	0.00
R4	0.00	52.25	0.00	0.00
$\bar{x}$	68.10	71.14	82.50	61.88
Total Phosphorus (ppm)				
R1	6.56	8.38	9.50	8.20
R2	6.05	5.40	0.00	7.93
R3	4.90	4.34	0.00	0.00
R4	0.00	5.08	0.00	0.00
$\bar{x}$	5.84	5.80	9.50	8.07
Total Kjeldahl Nitrogen (ppm)				
R1	1.63	1.33	1.07	1.73
R2	0.68	1.09	0.00	0.99
R3	0.30	0.83	0.00	0.00
R4	0.00	0.63	0.00	0.00
$\bar{x}$	0.87	0.97	1.07	1.36
Total Solids (ppm)				
R1	124.00	370.00	158.00	124.00
R2	140.00	141.70	0.00	136.00
R3	109.50	172.80	0.00	0.00
R4	0.00	0.84	0.00	0.00
$\bar{x}$	125.00	171.34	158.00	130.00
Dissolved Solids (ppm)				
R1	73.60	151.00	92.00	70.00
R2	96.00	102.30	0.00	72.00
R3	44.50	137.60	0.00	0.00
R4	0.00	68.00	0.00	0.00
$\bar{x}$	71.40	114.73	92.00	71.00

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TABLE B-2 (continued)

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	90-L	90-H	180-L	180-H
	Suspended Solids (ppm)			
R1	35.60	39.00	34.00	42.50
R2	32.00	23.10	0.00	24.50
R3	19.90	28.80	0.00	0.00
R4	0.00	35.00	0.00	0.00
$\bar{x}$	29.20	31.50	34.00	33.50
	Volatile Solids (ppm)			
R1	38.70	125.00	0.00	68.00
R2	28.00	72.00	0.00	38.00
R3	48.00	98.00	0.00	0.00
R4	0.00	52.00	0.00	0.00
$\bar{x}$	38.20	97.00	--	53.00
	BOD (ppm)			
R1	4.50	22.00	5.00	10.50
R2	5.00	4.00	0.00	2.00
R3	6.50	3.00	0.00	0.00
R4	0.00	3.00	0.00	0.00
$\bar{x}$	5.30	8.00	5.00	6.25
	COD (ppm)			
R1	31.50	62.00	41.00	110.50
R2	10.00	1.50	0.00	2.50
R3	28.50	5.50	0.00	0.00
R4	0.00	12.00	0.00	0.00
$\bar{x}$	23.50	20.30	41.00	56.50

† L = low

§ H = high

* R1-R4 = data for replications 1 through 4

+ $\bar{x}$ = average of four replications

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TABLE B-3. ANALYSIS OF RUNOFF WATERS ON MARCH 20, 1978

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	CK	45-L†	45-H [§]	90-L	90-H	135-L	135-H	180-L	180-H
Calcium (ppm)									
*R1	11.00	21.00	8.00	10.00	6.00	10.00	34.00	13.00	11.00
*R2	8.00	8.00	8.00	6.00	10.00	6.00	6.00	6.00	8.00
*R3	10.00	10.00	8.00	8.00	11.00	6.00	8.00	13.00	8.00
*R4	14.00	14.00	24.00	8.00	9.00	10.00	10.00	11.00	8.00
+ $\bar{x}$	11.00	13.00	12.00	8.00	9.00	8.00	15.00	11.00	9.00
Magnesium (ppm)									
R1	8.00	5.00	7.00	6.00	9.00	7.00	2.00	9.00	9.00
R2	13.00	9.00	10.00	6.00	6.00	7.00	9.00	13.00	5.00
R3	9.00	8.00	10.00	7.00	3.00	7.00	7.00	12.00	5.00
R4	6.00	12.00	6.00	9.00	6.00	9.00	2.00	13.00	6.00
$\bar{x}$	9.00	9.00	8.00	7.00	6.00	8.00	7.00	12.00	6.00
Sodium (ppm)									
R1	0.20	0.10	0.20	0.20	0.30	0.20	0.80	0.20	0.90
R2	0.10	0.20	0.30	0.30	0.40	0.30	0.30	0.50	0.50
R3	0.40	0.30	0.30	0.40	0.50	0.60	0.60	0.40	0.70
R4	0.10	0.20	0.70	0.70	0.40	0.60	0.40	0.50	0.80
$\bar{x}$	0.20	0.20	0.38	0.40	0.40	0.43	0.53	0.60	0.73
Potassium (ppm)									
R1	8.00	8.00	8.00	19.00	18.00	16.00	18.00	17.00	27.00
R2	11.00	11.00	8.00	17.00	10.00	18.00	14.00	18.00	14.00
R3	8.00	10.00	9.00	13.00	17.00	18.00	14.00	42.00	19.00
R4	7.00	10.00	14.00	20.00	15.00	13.00	11.00	20.00	15.00
$\bar{x}$	9.00	10.00	10.00	15.00	15.00	16.00	14.00	22.00	19.00
Nitrate Nitrogen (ppm)									
R1	0.94	0.98	0.80	0.76	0.99	0.31	1.49	0.80	0.39
R2	1.39	0.35	1.08	0.57	0.52	0.83	0.84	0.74	1.10
R3	0.84	0.66	0.99	0.91	1.03	0.97	1.04	3.05	0.36
R4	0.91	0.42	0.52	0.63	0.85	0.61	0.68	0.70	0.44
$\bar{x}$	1.02	0.60	0.85	0.72	0.85	0.68	1.01	1.32	0.57
Chloride (ppm)									
R1	2.50	2.00	3.00	4.00	6.00	3.50	2.50	3.00	4.00
R2	2.00	3.00	3.80	3.00	2.20	2.50	3.00	3.00	3.00
R3	2.50	2.50	3.00	2.00	5.00	2.50	3.80	4.20	2.50
R4	1.50	2.50	2.20	2.80	4.40	2.00	2.50	2.80	2.80
$\bar{x}$	2.13	2.50	3.00	2.95	4.40	2.63	2.95	3.25	3.08

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TABLE B-3 (continued)

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	CK	45-L	45-H	90-L	90-H	135-L	135-H	180-L	180-H
pH									
R1	7.15	7.05	7.10	7.10	7.20	7.14	7.25	7.14	7.02
R2	7.09	7.11	7.18	7.13	7.12	7.14	7.18	7.13	7.13
R3	7.05	7.10	7.13	7.08	7.08	7.17	7.16	7.03	7.17
R4	7.08	7.10	7.09	7.08	7.13	7.13	7.14	7.15	7.15
$\bar{x}$	7.09	7.09	7.13	7.10	7.13	7.15	7.18	7.11	7.12
Electrical Conductivity (μ mhos/cm)									
R1	133.00	138.00	126.00	122.00	123.00	108.00	169.00	113.00	195.00
R2	115.00	92.00	84.00	108.00	93.00	121.00	104.00	111.00	103.00
R3	104.00	93.00	97.00	122.00	140.00	116.00	106.00	222.00	113.00
R4	103.00	104.00	162.00	138.00	119.00	102.00	93.00	129.00	94.00
$\bar{x}$	114.00	105.00	117.00	123.00	119.00	112.00	118.00	144.00	126.00
Total Phosphorus (ppm)									
R1	0.86	1.71	2.02	5.08	4.22	7.34	5.02	8.72	12.70
R2	1.29	2.75	1.16	4.22	3.29	4.28	3.73	7.34	6.89
R3	1.35	2.02	2.51	4.05	4.97	8.54	4.13	21.11	8.42
R4	3.06	3.98	4.41	9.33	4.16	9.03	2.60	12.39	8.87
$\bar{x}$	1.64	2.62	2.53	5.67	4.16	7.30	3.87	12.39	9.22
Total Kjeldahl Nitrogen (ppm)									
R1	0.93	1.31	1.59	1.26	2.80	3.36	2.01	3.45	1.45
R2	2.70	2.10	2.15	1.26	1.59	2.89	2.89	1.35	1.21
R3	1.31	2.94	2.80	1.68	0.70	2.85	1.96	2.19	3.17
R4	0.65	1.87	2.43	3.13	1.70	1.49	1.17	1.21	2.99
$\bar{x}$	1.40	2.06	2.24	1.83	1.70	2.65	2.01	2.05	2.21
Total Solids (ppm)									
R1	96.00	108.00	92.00	108.00	100.00	164.00	192.00	152.00	120.00
R2	96.00	100.00	120.00	104.00	116.00	116.00	104.00	104.00	52.00
R3	104.00	68.00	104.00	200.00	120.00	152.00	104.00	252.00	140.00
R4	72.00	84.00	144.00	92.00	112.00	84.00	104.00	92.00	108.00
$\bar{x}$	92.00	90.00	115.00	126.00	112.00	129.00	126.00	150.00	105.00
Dissolved Solids (ppm)									
R1	84.00	100.00	52.00	80.00	72.00	120.00	196.00	84.00	128.00
R2	56.00	76.00	72.00	76.00	136.00	84.00	84.00	100.00	84.00
R3	72.00	116.00	128.00	84.00	92.00	240.00	152.00	216.00	64.00
R4	92.00	80.00	100.00	96.00	100.00	76.00	140.00	136.00	76.00
$\bar{x}$	76.00	93.00	88.00	84.00	100.00	130.00	143.00	134.00	88.00

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TABLE B-3 (continued)

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	CK	45-L	45-H	90-L	90-H	135-L	135-H	180-L	180-H
Suspended Solids (ppm)									
R1	6.00	4.00	4.00	18.00	6.00	4.00	206.00	8.00	12.00
R2	2.00	4.00	6.00	10.00	8.00	6.00	4.00	10.00	6.00
R3	4.00	70.00	20.00	26.00	4.00	166.00	32.00	6.00	10.00
R4	6.00	6.00	12.00	74.00	5.00	12.00	54.00	6.00	14.00
$\bar{x}$	5.00	21.00	11.00	26.00	5.00	47.00	74.00	8.00	11.00
Volatile Solids (ppm)									
R1	40.00	32.00	24.00	28.00	48.00	40.00	56.00	40.00	32.00
R2	52.00	20.00	100.00	24.00	48.00	48.00	32.00	20.00	29.00
R3	40.00	40.00	64.00	29.00	60.00	56.00	52.00	64.00	32.00
R4	4.00	28.00	36.00	36.00	39.00	36.00	40.00	16.00	24.00
$\bar{x}$	34.00	30.00	56.00	29.00	39.00	45.00	45.00	35.00	29.00
BOD (ppm)									
R1	4.00	6.00	7.00	8.00	10.00	8.00	6.00	8.00	15.00
R2	7.00	7.00	5.00	8.00	7.00	9.00	7.00	8.00	7.00
R3	10.00	7.00	7.00	7.00	10.00	10.00	7.00	11.00	10.00
R4	6.00	9.00	5.00	11.00	9.00	7.00	8.00	9.00	7.00
$\bar{x}$	7.00	7.00	6.00	9.00	9.00	9.00	7.00	9.00	10.00
COD (ppm)									
R1	20.00	20.00	20.00	13.00	16.00	28.00	32.00	45.00	35.00
R2	16.00	9.00	15.00	12.00	25.00	14.00	16.00	48.00	18.00
R3	25.00	39.00	9.00	60.00	23.00	37.00	33.00	51.00	43.00
R4	10.00	9.00	32.00	31.00	21.00	21.00	29.00	23.00	12.00
$\bar{x}$	18.00	19.00	19.00	29.00	21.00	25.00	28.00	42.00	27.00

† L = low

§ H = high

* R1-R4 = data for replications 1 through 4

+ $\bar{x}$ = average of four replications

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APPENDIX C

PLANT POPULATIONS AND CROP YIELDS

Results for all plant observations for individual treatment plots are given.

Plant populations	(Table C-1)
Analysis of variance--plant populations	(Table C-2)
Yield of corn silage	(Table C-3)
Analysis of variance--yield of corn silage	(Table C-4)
Yield of ear corn	(Table C-5)
Analysis of variance--yield of ear corn	(Table C-6)

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TABLE C-1. PLANT POPULATIONS (PLANTS/HA)

	CK	45-L†	45-H§	90-L	90-H	135-L	135-H	180-L	180-H
1974									
*R1	47359	47359	47359	43054	43054	34443	43054	34443	34443
*R2	51663	47359	55970	47359	51663	47359	34443	34443	34443
*R3	47359	51663	43054	34443	43054	38750	40900	43054	25831
*R4	51663	47359	47359	38750	43054	38750	34443	34443	27986
+ $\bar{x}$	49511	48435	48436	40902	45206	39826	38210	36596	30676
1975									
R1	34803	35879	35161	30496	26192	26192	22244	27986	29780
R2	29062	35879	36238	32291	30138	30138	31932	29062	27986
R3	38032	35161	31932	30856	29062	30138	33009	31573	14710
R4	35520	32650	35161	33008	29780	27986	27627	30856	28703
$\bar{x}$	34354	34892	34623	31663	28793	28614	28703	29869	25295
1976									
R1	38749	36596	41978	38749	36955	34444	39825	41620	36955
R2	38032	41978	41620	36597	38749	38032	40543	37673	38032
R3	44131	37673	39467	35879	39467	36238	33367	38032	34085
R4	40543	39826	38032	37314	38032	35161	38390	35520	35161
$\bar{x}$	40364	39018	40274	37135	38301	35969	38031	38211	36058
1977									
R1	36744	34120	31493	28869	36744	31493	34120	34120	34120
R2	31493	31493	34120	34120	31493	28869	31493	36744	34120
R3	31493	34120	31493	31493	34120	31493	31493	34120	31493
R4	34120	34120	31493	31493	34120	34120	34120	31493	31493
$\bar{x}$	33463	33463	32150	31494	34119	31494	32807	34119	32807

† L = low

§ H = high

* R1-R4 = data for replications 1 through 4

+ $\bar{x}$ = average of four replications

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TABLE C-2. ANALYSIS OF VARIANCE -- PLANT POPULATIONS

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Source	DF [†]	SS ^{††}	MS [†]	F ^{††}
Row	3	---	---	93.26**
Column	8	---	---	12.25**
Interaction	24.00	---	---	3.40
Error	180	---	---	
Total	143	---		
Column Contrasts	NUM DF [§]		DEN DF ^{§§}	F
CK vs 45L	1.00		162.0	0
CK vs 45H	1.00		162.0	0
CK vs 90L	1.00		162.0	14**
CK vs 90H	1.00		162.0	6*
CK vs 135L	1.00		162.0	24**
CK vs 135H	1.00		162.0	20**
CK vs 180L	1.00		162.0	18**
CK vs 180H	1.00		162.0	54**
High vs Low	1.00		162.0	1

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+ DF = degrees of freedom
 †† SS = sum of squares
 † MS = mean square
 †† F = tabular F
 § NUM = numerator
 §§ DEN = denominator
 * F.05 = 3.84 significant at the 95 percent probability level
 ** F.01 = 6.63 significant at the 95 percent probability level

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TABLE C-3. YIELD OF CORN SILAGE (MT/HA)

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	CK	45-L†	45-H§	90-L	90-H	135-L	135-H	180-L	180-H
<u>1974</u>									
*R1	3.99	7.77	6.81	7.39	6.54	7.97	6.18	8.47	6.18
*R2	3.76	9.16	6.52	7.46	8.02	8.09	7.75	7.06	7.14
*R3	9.27	8.18	5.87	11.36	8.31	4.41	6.52	7.71	5.76
*R4	5.64	8.78	7.68	3.94	8.58	3.45	6.27	7.48	6.41
+ $\bar{x}$	5.67	8.47	6.72	7.54	7.86	5.98	6.68	7.68	6.37
<u>1975</u>									
R1	9.25	7.38	9.55	7.28	4.27	4.33	3.35	6.26	4.37
R2	8.60	9.08	8.48	5.61	5.75	5.24	3.57	4.68	4.63
R3	6.88	6.93	6.86	7.23	4.43	5.62	4.10	5.79	2.42
R4	7.08	8.62	7.42	7.78	5.98	5.84	3.38	5.88	4.00
$\bar{x}$	7.95	8.00	8.08	6.98	5.11	5.26	3.60	5.65	3.86
<u>1976</u>									
R1	3.63	3.06	2.54	3.21	4.51	3.88	4.35	3.67	3.38
R2	2.68	3.37	3.59	2.50	3.54	2.20	3.29	3.61	4.27
R3	2.67	2.81	2.61	3.75	2.93	3.98	3.71	3.37	3.45
R4	2.35	3.03	2.33	2.78	3.11	3.43	3.65	4.00	3.04
$\bar{x}$	2.83	3.07	2.77	3.06	3.52	3.37	3.75	3.66	3.54
<u>1977</u>									
R1	9.93	10.09	9.66	9.05	8.34	7.73	7.35	8.34	7.26
R2	7.08	9.82	10.02	7.51	8.34	7.55	7.13	7.84	7.78
R3	9.64	8.11	10.27	9.48	8.14	6.28	8.43	6.63	6.43
R4	9.05	10.38	9.41	7.98	8.45	6.99	6.97	7.55	5.94
$\bar{x}$	8.93	9.60	9.84	8.51	8.32	7.14	7.47	7.59	6.85

† L = low

§ H = high

* R1-R4 = data for replications 1 through 4

+ $\bar{x}$ = average of four replications

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TABLE C-4. ANALYSIS OF VARIANCE -- YIELD OF CORN SILAGE

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Source	DF [†]	SS ^{††}	MS [†]	F ^{††}
Row	3.00	480.07	160.02	142.99**
Column	8.00	64.96	8.12	7.26**
Interaction	24.00	103.52	4.31	3.85**
Error	108.00	120.86	1.12	
Total	143.00	769.41		
<u>Column Contrasts</u>		<u>NUM DF[§]</u>	<u>DEN DF^{§§}</u>	<u>F</u>
CK vs 45L		1.00	162.0	6.34*
CK vs 45H		1.00	162.0	1.84NS#
CK vs 90L		1.00	162.0	0.22NS
CK vs 90H		1.00	162.0	0.14NS
CK vs 135L		1.00	162.0	5.88*
CK vs 135H		1.00	162.0	6.71*
CK vs 180L	5-1/2"	1.00	162.0	0.28NS
CK vs 180H		1.00	162.0	10.12**

† DF = degrees of freedom

†† SS = sum of squares

† MS = mean square

†† F = tabular F

§ NUM = numerator

§§ DEN = denominator

* F.05 = 3.84 significant at the 95 percent probability level

** F.01 = 6.63 significant at the 99 percent probability level

NS = non-significant

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TABLE C-5. YIELD OF EAR CORN (MT/HA)

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	CK	45-L†	45-H§	90-L	90-H	135-L	135-H	180-L	180-H
					<u>1974</u>				
*R1	1.02	2.05	1.09	2.40	2.44	2.22	2.23	2.50	1.89
*R2	1.34	2.59	2.17	1.98	1.91	1.99	2.98	2.30	2.49
*R3	1.65	1.39	0.67	2.56	1.76	1.60	1.67	2.02	2.55
*R4	1.65	1.93	1.16	2.50	1.76	1.81	1.91	2.14	0.94
+ $\bar{x}$	1.42	1.99	1.27	2.25	1.97	1.91	2.20	2.24	1.97
					<u>1975</u>				
R1	1.86	2.65	1.95	3.05	2.34	1.09	2.72	1.81	0.40
R2	1.41	2.03	3.92	1.93	1.96	1.51	0.69	1.85	1.31
R3	1.15	2.02	1.98	2.97	2.99	1.98	2.19	2.11	0.20
R4	1.17	2.33	1.27	2.76	2.49	1.69	1.16	2.12	1.26
$\bar{x}$	1.40	2.26	2.28	2.68	2.45	1.57	1.69	1.97	0.79
					<u>1976</u>				
R1	0.63	0.00	0.00	0.21	0.52	1.02	0.51	0.48	0.51
R2	0.00	0.20	0.79	0.08	0.18	0.17	0.10	0.56	0.49
R3	0.00	0.27	0.13	0.42	0.36	1.04	0.59	0.40	1.05
R4	0.00	0.13	0.13	0.23	0.42	0.26	1.33	0.16	0.00
$\bar{x}$	0.16	0.15	0.26	0.24	0.37	0.62	0.63	0.40	0.51
					<u>1977</u>				
R1	6.15	5.96	4.69	4.74	4.10	4.21	3.28	4.07	3.22
R2	5.39	6.18	4.19	4.02	5.05	4.74	4.20	3.70	3.21
R3	5.63	4.51	5.62	4.00	4.07	3.57	4.99	2.55	3.10
R4	4.48	3.94	4.97	2.78	3.90	3.59	2.99	2.77	2.94
$\bar{x}$	5.41	5.15	4.87	3.89	4.28	4.03	3.87	3.27	3.12

† L = low

§ H = high

* R1-R4 = data for replications 1 through 4

+ $\bar{x}$ = average of four replications

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TABLE C-6. ANALYSIS OF VARIANCE -- YIELD OF EAR CORN

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Source	DF ⁺	SS ⁺⁺	MS [†]	F ^{††}
Row	3.00	270.35	90.12	298.64**
Column	8.00	6.63	0.83	2.75**
Interaction	24.00	29.98	1.25	4.14**
Error	108.00	32.59	0.30	
Total	143.00	339.54		

Column Contrasts	NUM DF [§]	DEN DF ^{§§}	F
CK vs 45L	1.00	162.0	2.24NS#
CK vs 45H	1.00	162.0	0.15NS
CK vs 90L	1.00	162.0	0.73NS
CK vs 90H	1.00	162.0	0.77NS
CK vs 135L	1.00	162.0	0.11NS
CK vs 135H	1.00	162.0	0.00NS
CK vs 180L	1.00	162.0	0.41NS
CK vs 180H	1.00	162.0	6.58*
High vs Low	1.00	162.0	1.79NS

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+ DF = degrees of freedom
 ++ SS = sum of squares
 † MS = mean square
 †† F = tabular F
 § NUM = numerator
 §§ DEN = denominator
 * F.05 = 3.84 significant at the 95 percent probability level
 ** F.01 = 6.63 significant at the 99 percent probability level
 # NS = non-significant

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